Quantifying Gas Hydrate Deposits

Implications for Petroleum Systems and Secondary Target and Seal Assessment in large Biogenic Gas Plays

Dan McConnell- Global Product Manager Gas Hydrates and Marine Minerals

MHAC Meeting Dec 2 2020 (adapted from presentation given at AAPG Annual Meeting Sept 29-Oct 1)

Today's Discussion

1. Gas hydrates in the petroleum system
2. Biogenic gas systems
3. Linkage between gas hydrates and biogenic gas systems
4. Instability of gas hydrates and effect on biogenic systems
5. Eastern Med example
6. Myanmar example
7. Quantifying gas hydrates
8. Conclusions and Questions

1. Gas hydrates in the petroleum system

Gas Hydrate Fundamentals-

Solid composed of light gases and water

PT conditions where gas hydrate can form are on continental margins and in the arctic.

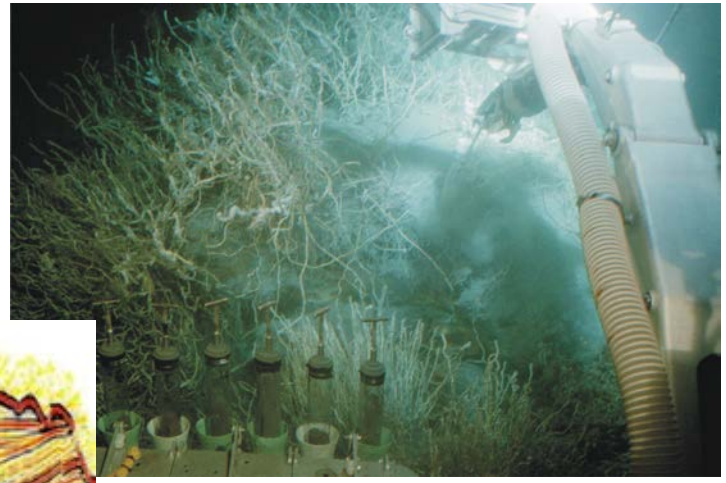
Base of gas hydrate container discovered as a bottom simulating reflector in seismic data in 1970s

Found at deepwater hydrocarbon seeps in 1980s

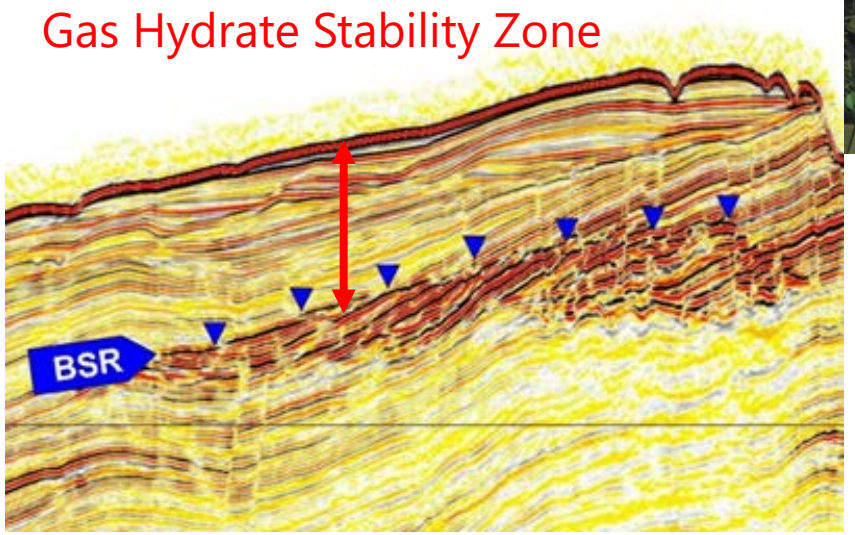
D. McConnell

A dense energy source
164 m^3 gas/ 1 m^3 gas hydrate

More gas than a shallow gas reservoir
Less gas than a deep gas reservoir

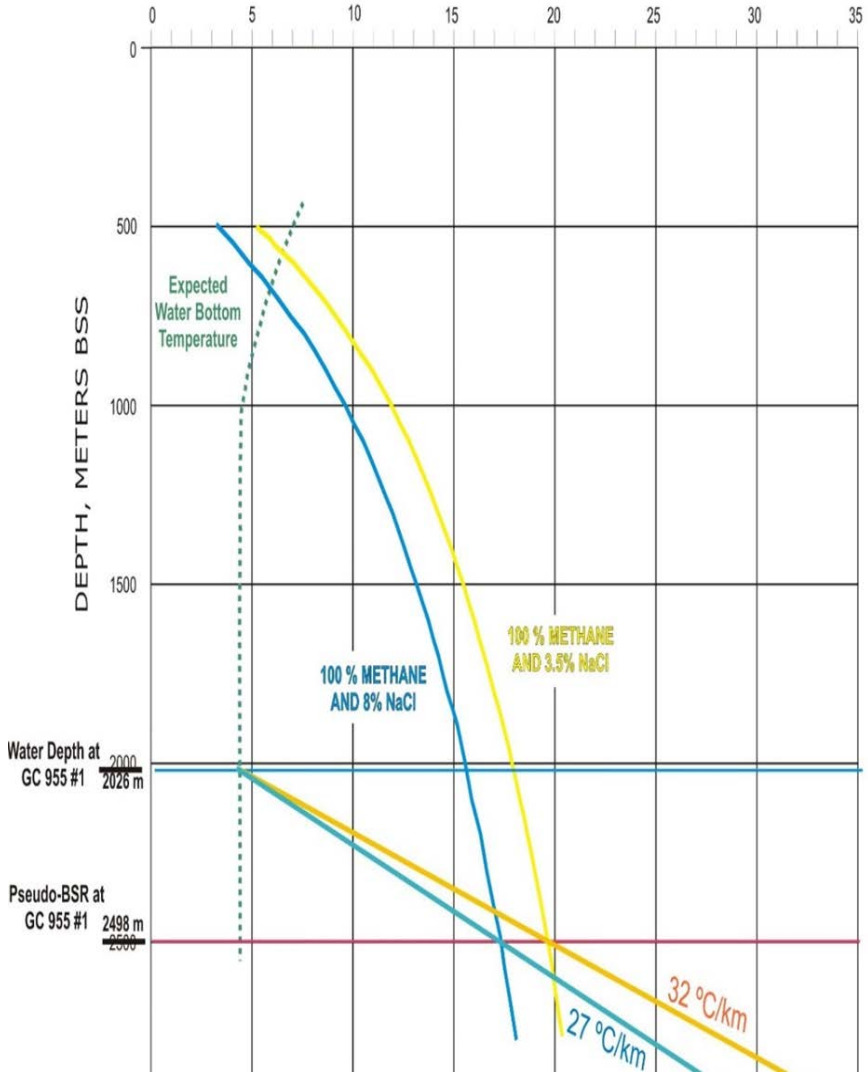


D. McConnell

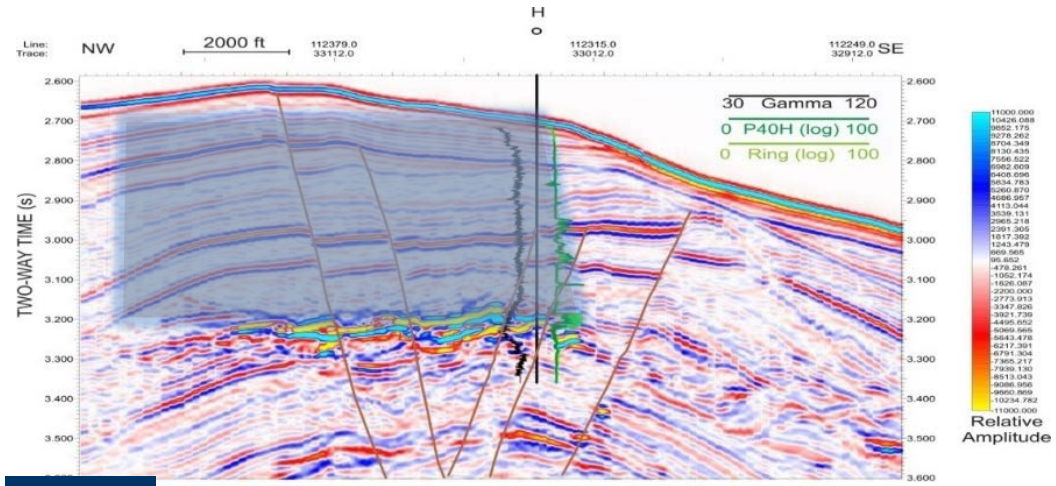


MH 21 Consortium

Gas Hydrate Stability Zone



Often not a BSR but the Topmost Gassy Sediment Trend Consistent with Gas Hydrate P/T Boundary



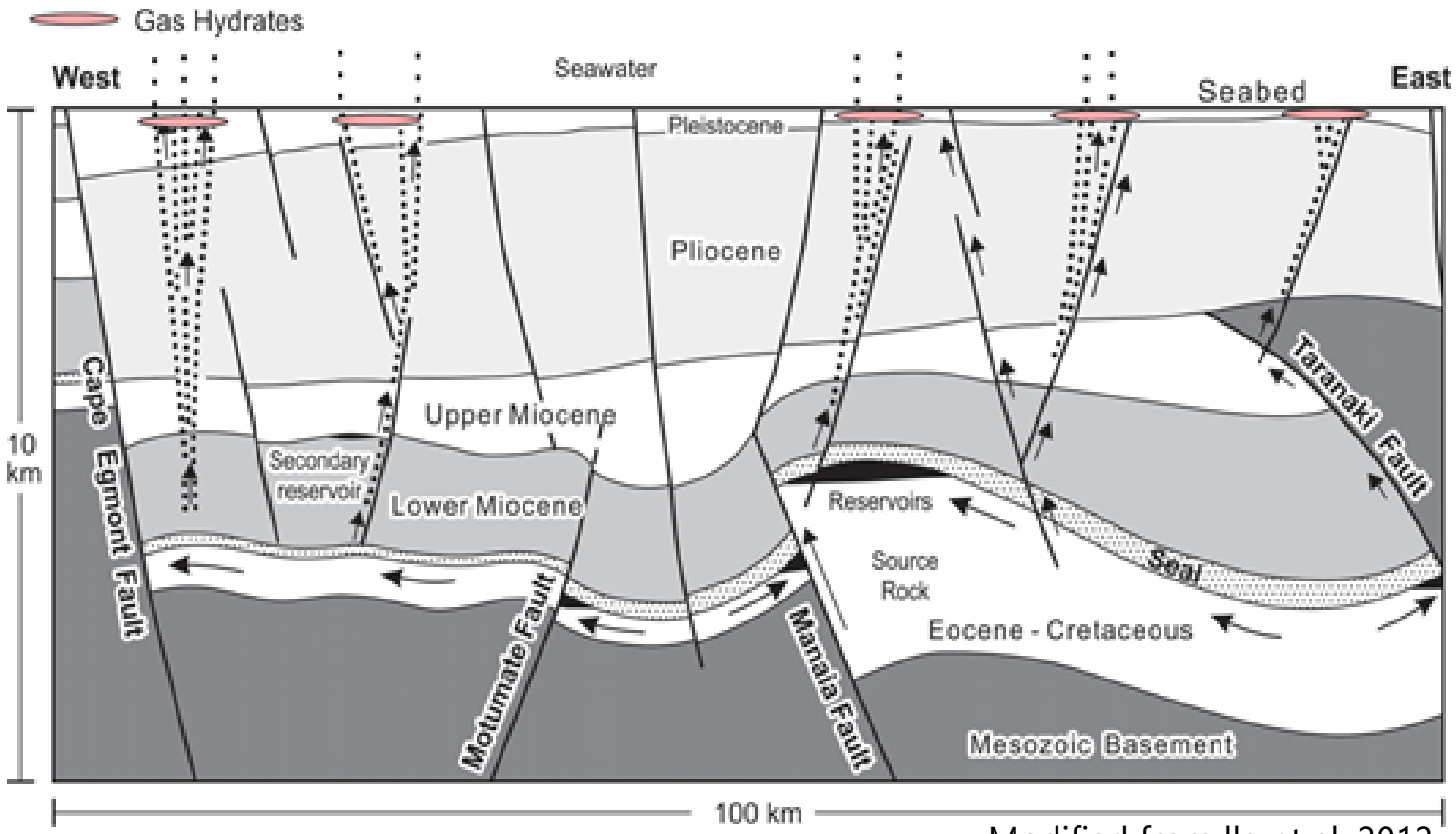
Interpretation by McConnell- AOA and

Gas hydrates- a component of the petroleum system, but help understand biogenic plays

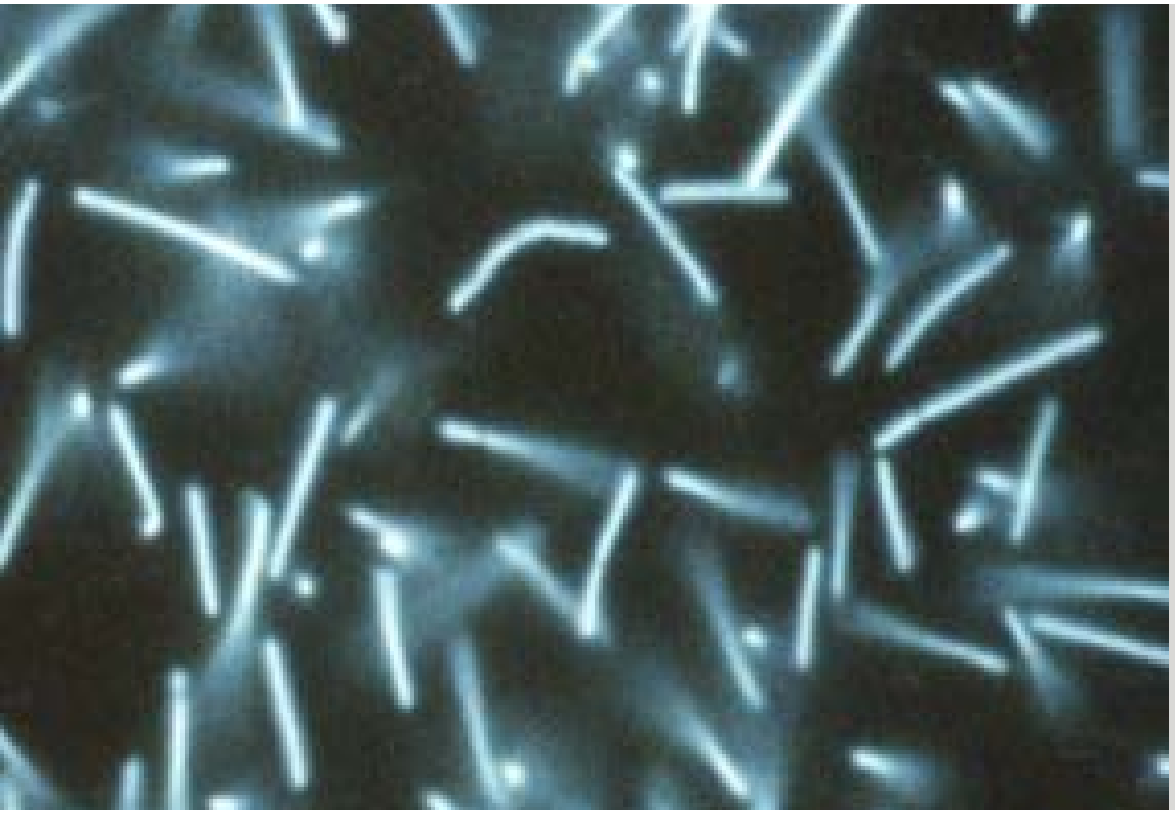
Gas hydrate can show there is an active petroleum system.

Seep geochemistry has of tracing secondary or tertiary migration from a deep thermogenic reservoir

- Most prolific gas hydrates systems are directly related to biogenic gas preservation
- **Gas hydrates are important for exploring and evaluating conventional biogenic gas plays**



Modified from Ilg et al. 2012

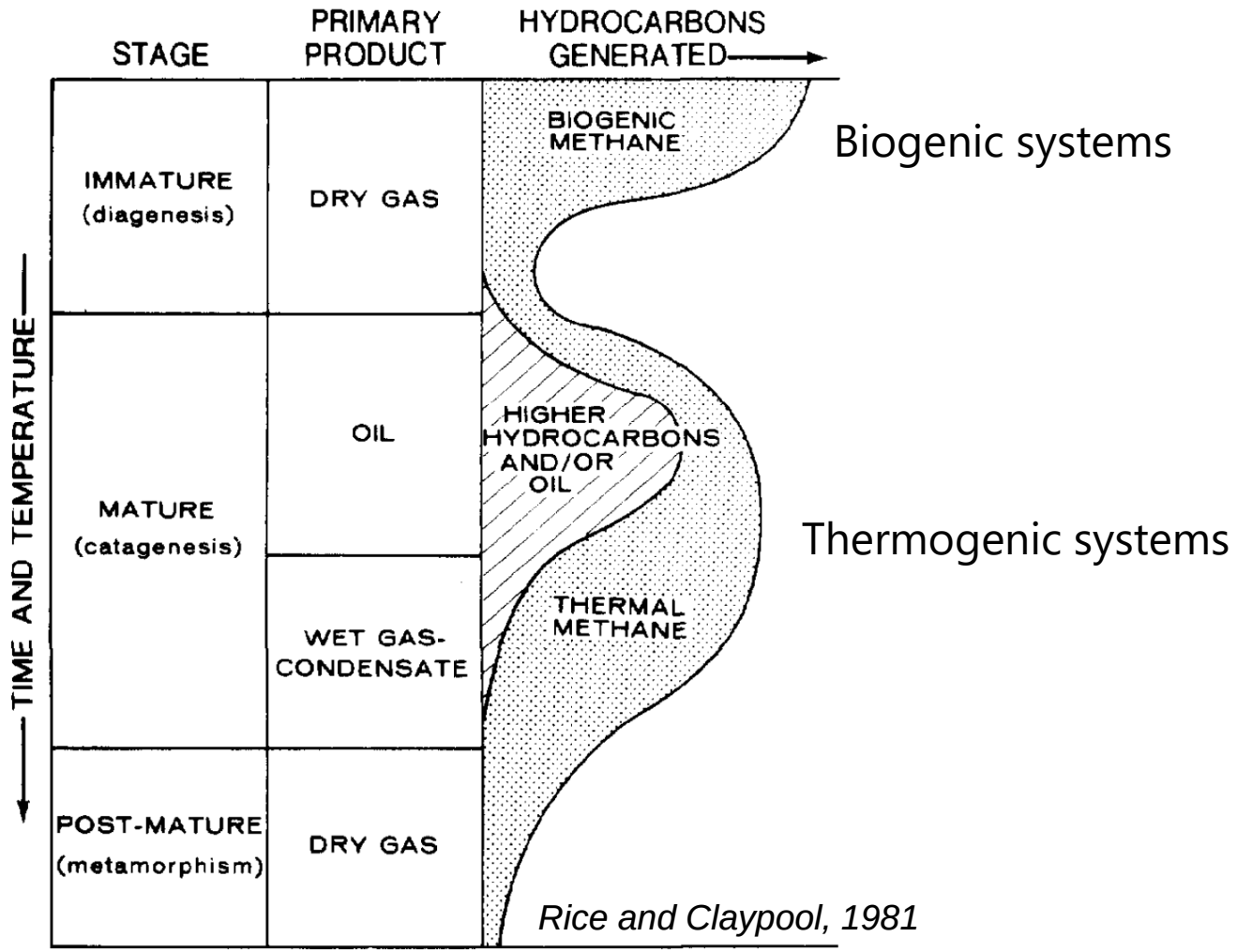


2. Biogenic gas systems

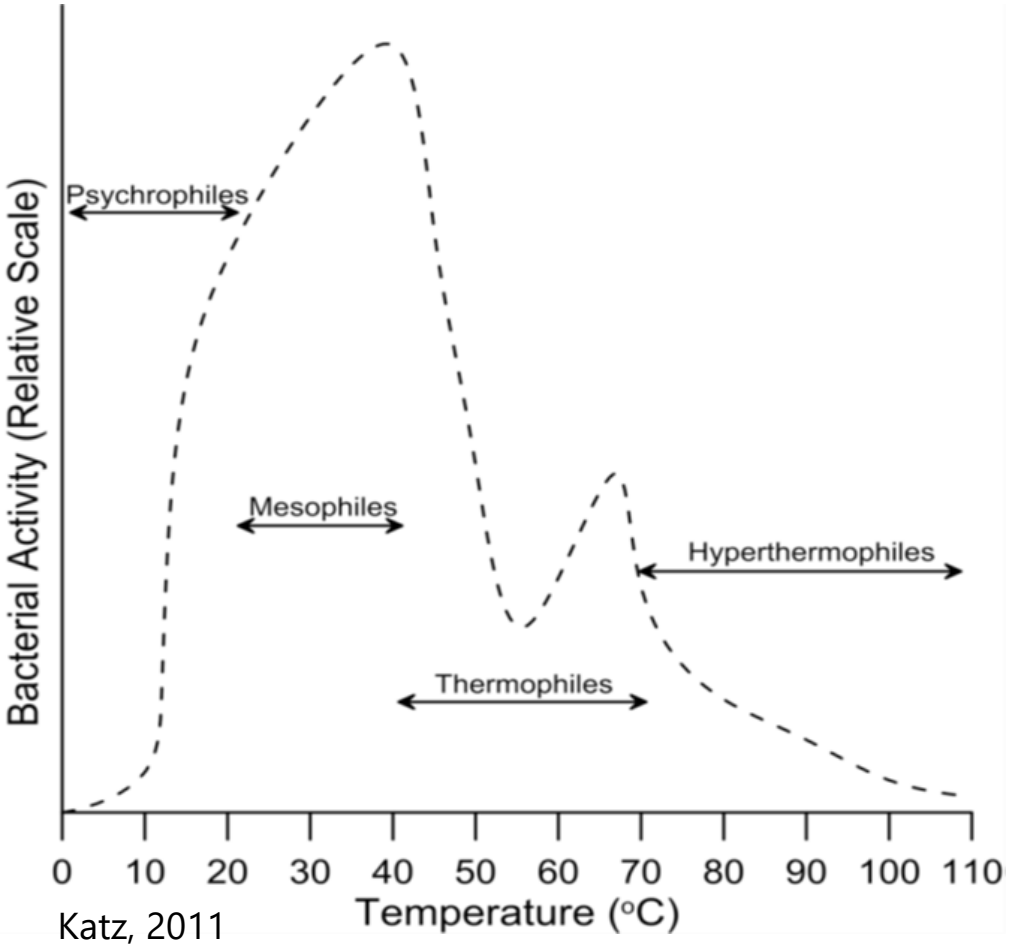
First, the basin produces and expels biogenic gas

Every basin goes through a biogenic gas generation phase

- In most oil and gas plays the hydrocarbons generated by microbial processes has been flushed through the system along with pods of biogenic gas that had once, in the right settings, been in gas hydrates.
- Biogenic systems – favor deepwater, rapid sedimentation, labile organic matter, stratigraphic or structural traps, compaction seals, formation of gas hydrates



Conventional Biogenic Resources



Katz, 2011

Rapid Sedimentation. Young reservoirs. Reservoir temperatures are 40°-45°

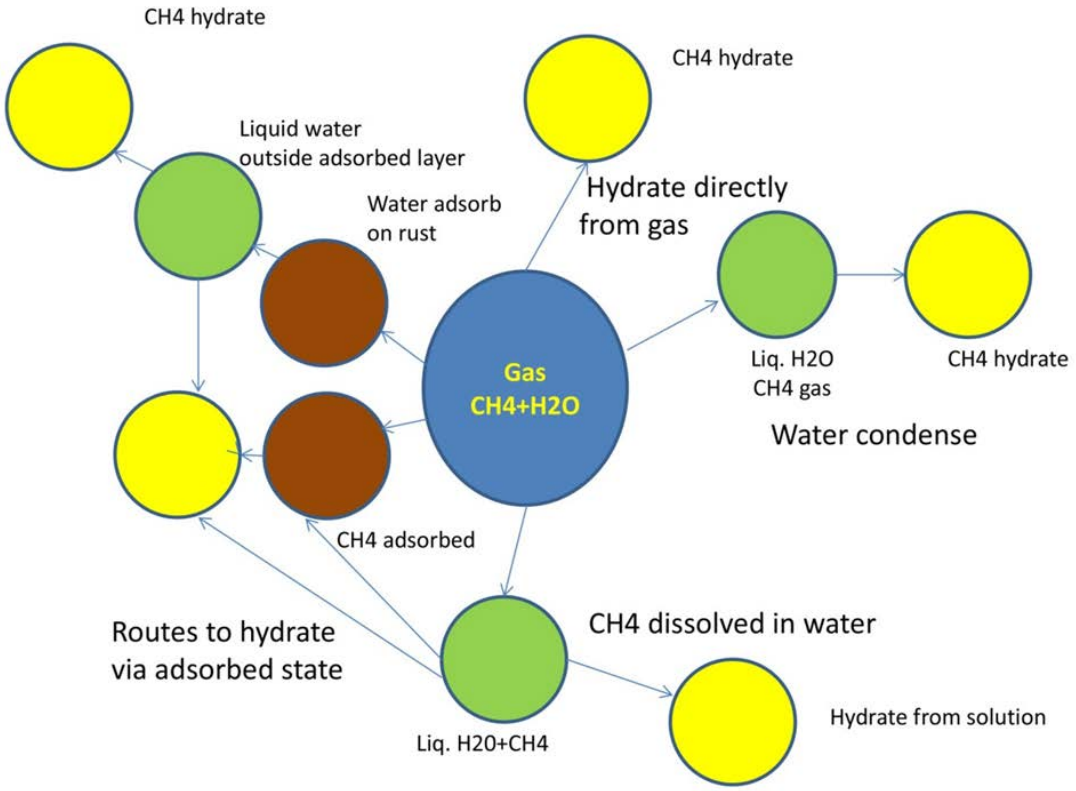
Economic accumulations of biogenic gas may form in less than 100,000 years

When reservoir temperatures exceed 60°, then the gas may have been generated at shallower depths and was subsequently buried, but there are microbes that thrive at these temperatures provided there is adequate pore space.

Vertical and lateral migration is needed to accumulate large gas amounts, in-situ microbial gas processes are not thought to be enough.

PVT conditions for bubble formation.

Simple traps with fetch, not fault dependent

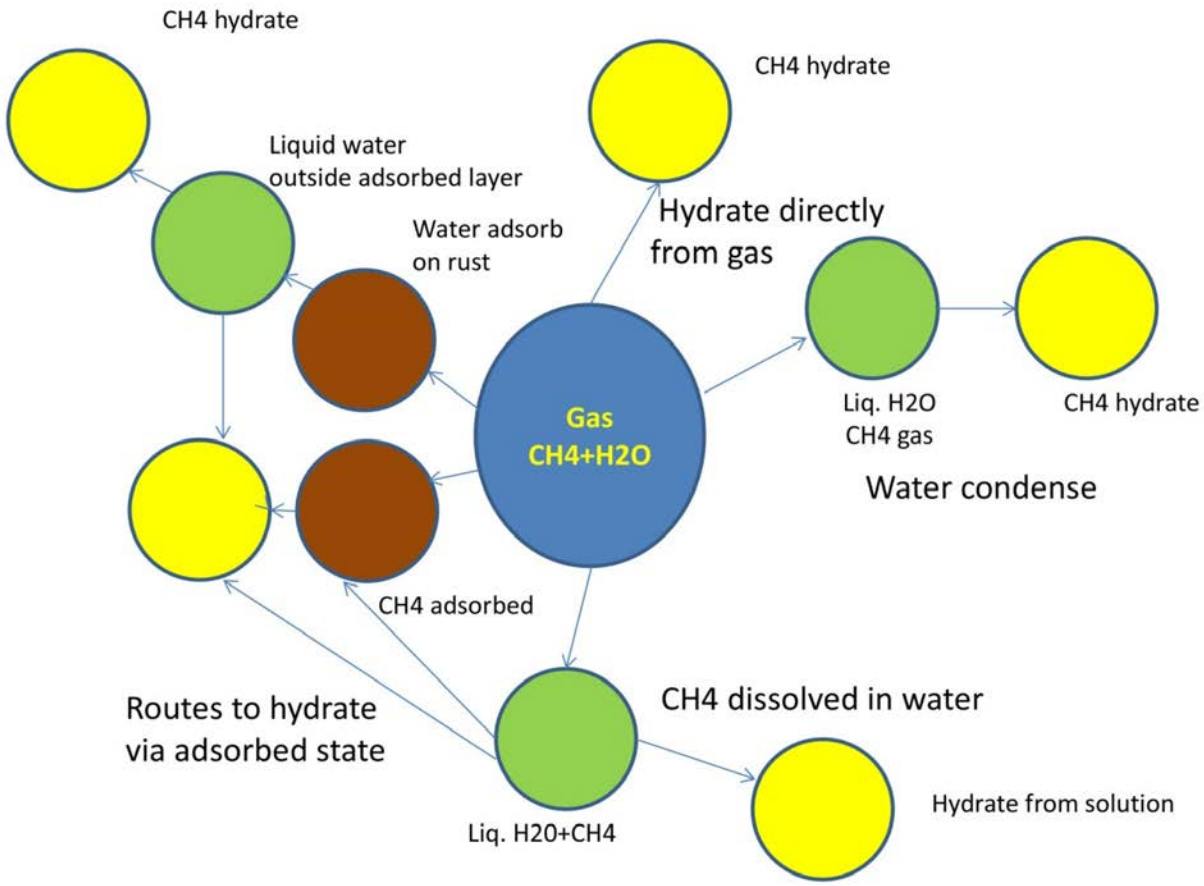


3. Linkage between gas hydrates and biogenic gas systems
4. Instability of gas hydrate systems

Gas Hydrates tend not to be retained in sediments because they are unstable

Scientists that study CO2 sequestration and methane production from hydrates conclude that equilibrium is never reached.

- Explains why a modest decrease in pressure will start gas and water production from gas hydrate. Irreducible water.
- Undersaturated pore waters driven by compaction will destroy gas hydrates



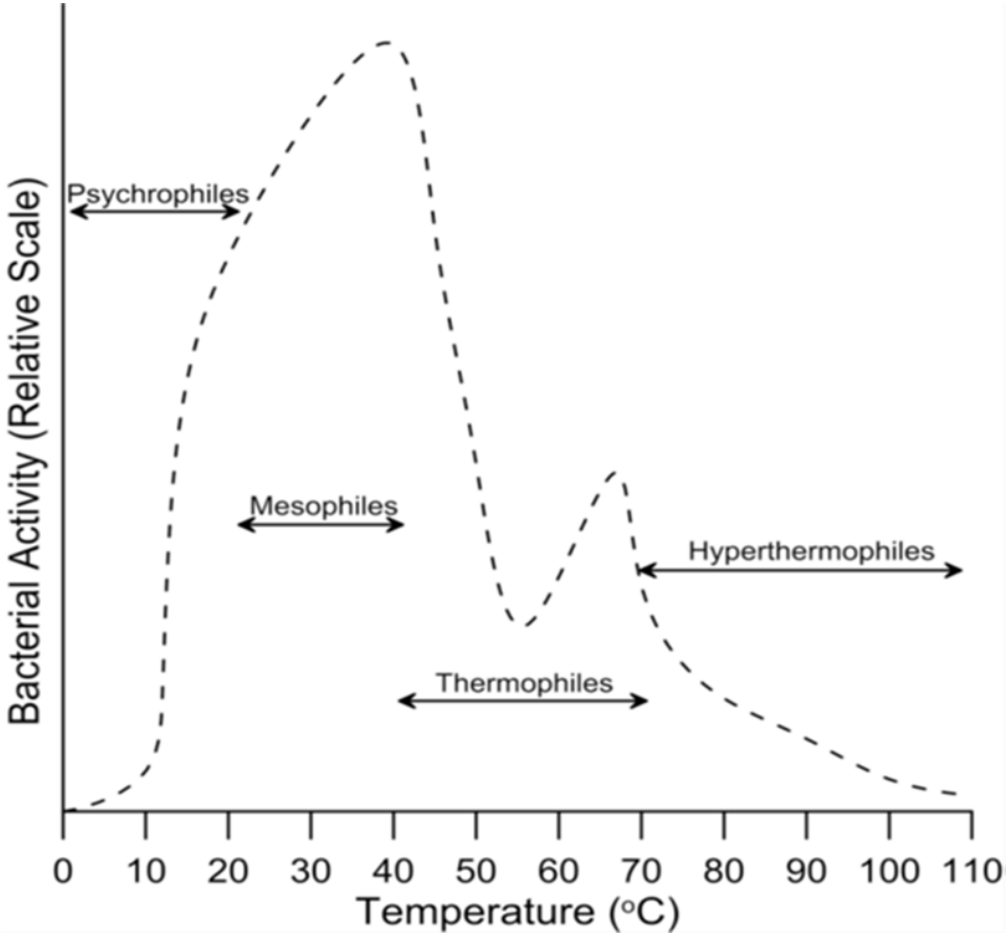
Kvamme et al., 2020

Gas expansion and biogenic gas generation in Deepwater

Bg is the gas expansion factor. Gas hydrates are fixed at 164.

Peak biogenic gas generation between 20° and 45° C and another between 60° and 70°C

Biogenic gas plays are more favorable in deepwater because of high pressures, and less prone to shrinkage when trapped by compaction

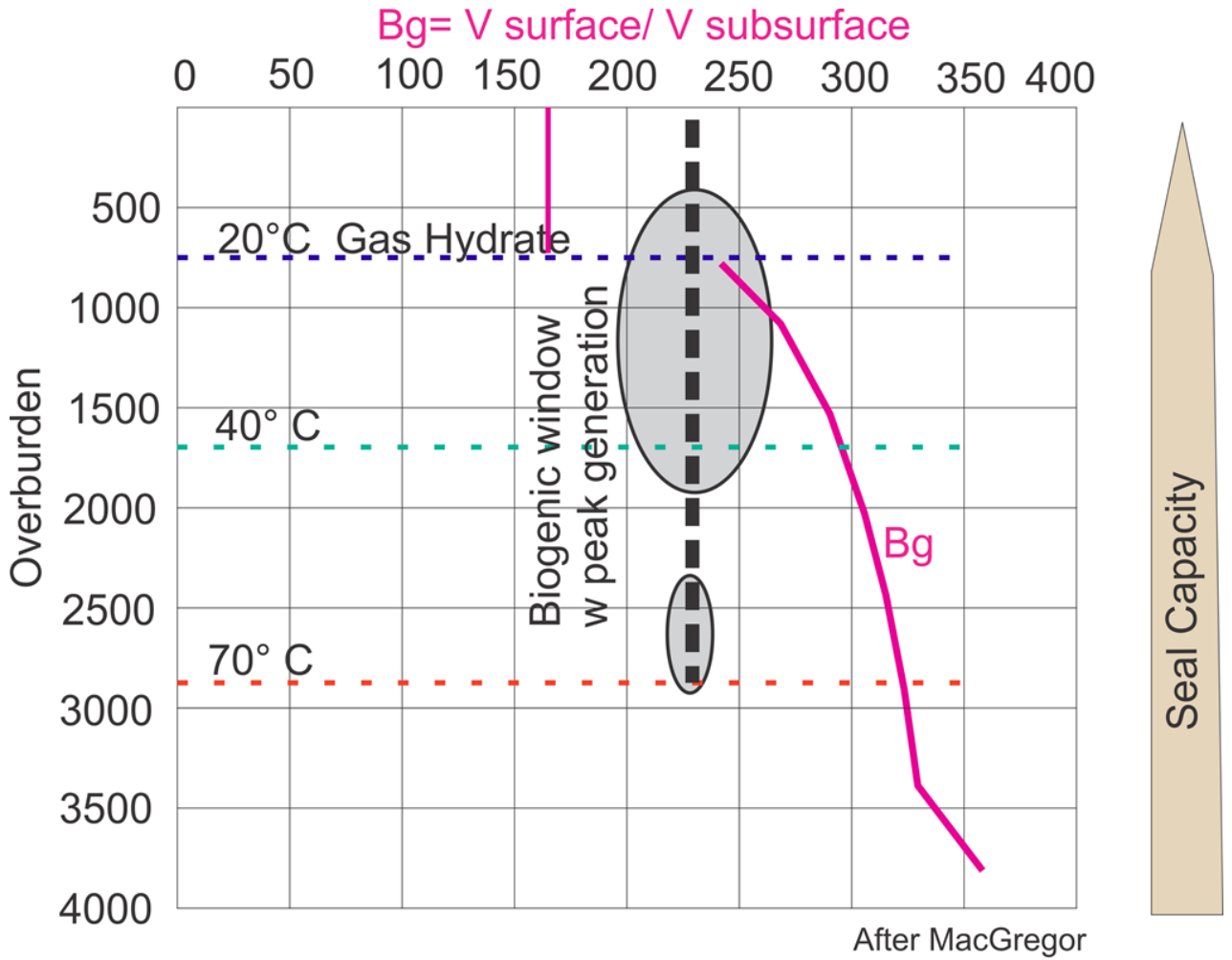


Gas expansion and biogenic gas generation in Deepwater

Bg is the gas expansion factor. Gas hydrates are fixed at 164.

Peak biogenic gas generation between 20° and 45° C and another between 60° and 70°C

Biogenic gas plays are more favorable in deepwater because of high pressures, and less prone to shrinkage when trapped by compaction



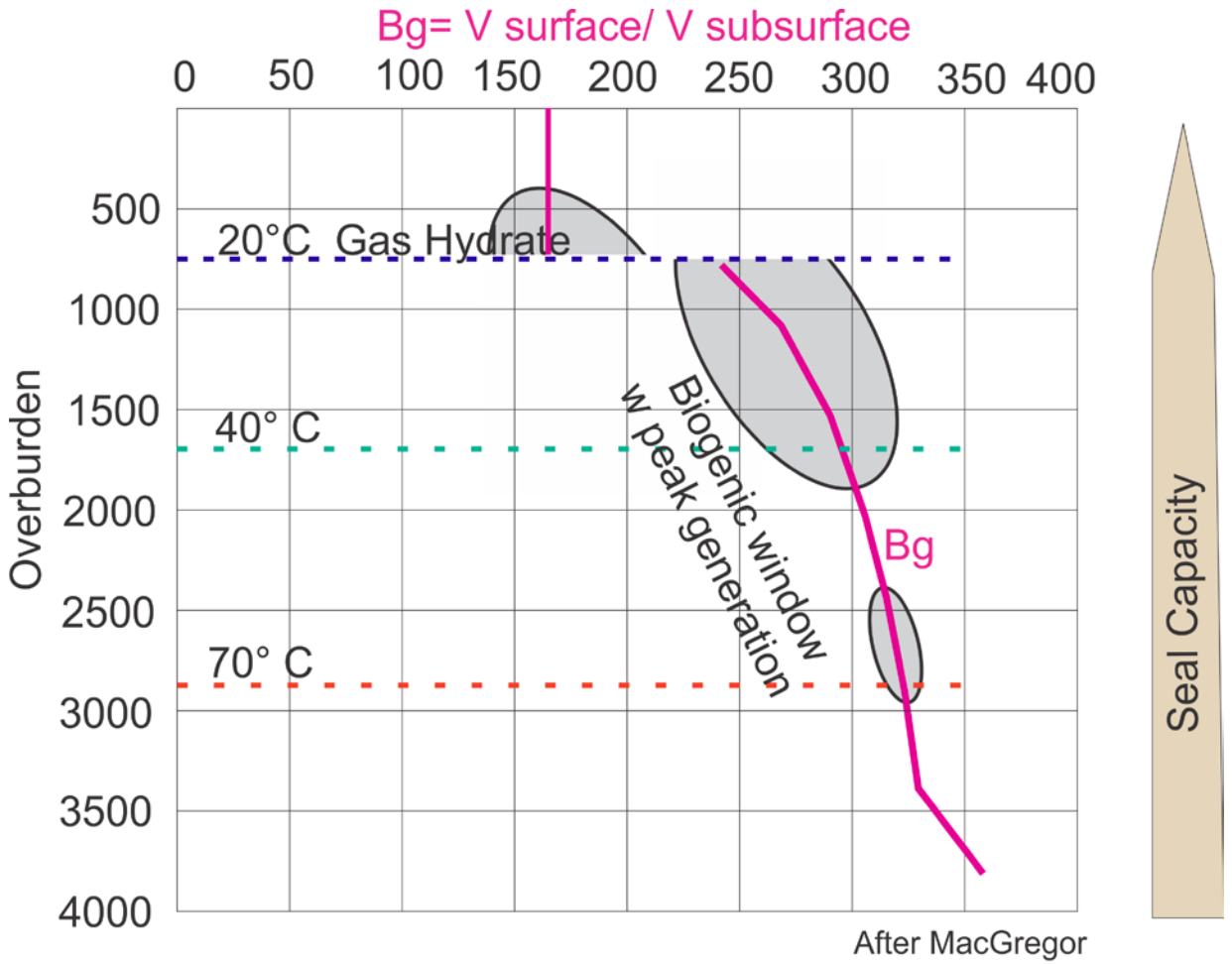
Bg at hydrostatic; 21° C/km; 1500 m water depth; 5 deg

Gas expansion and biogenic gas generation in Deepwater

Bg is the gas expansion factor. Gas hydrates are fixed at 164.

Peak biogenic gas generation between 20° and 45° C and another between 60° and 70°C

Biogenic gas plays are more favorable in deepwater because of high pressures, and less prone to shrinkage when trapped by compaction

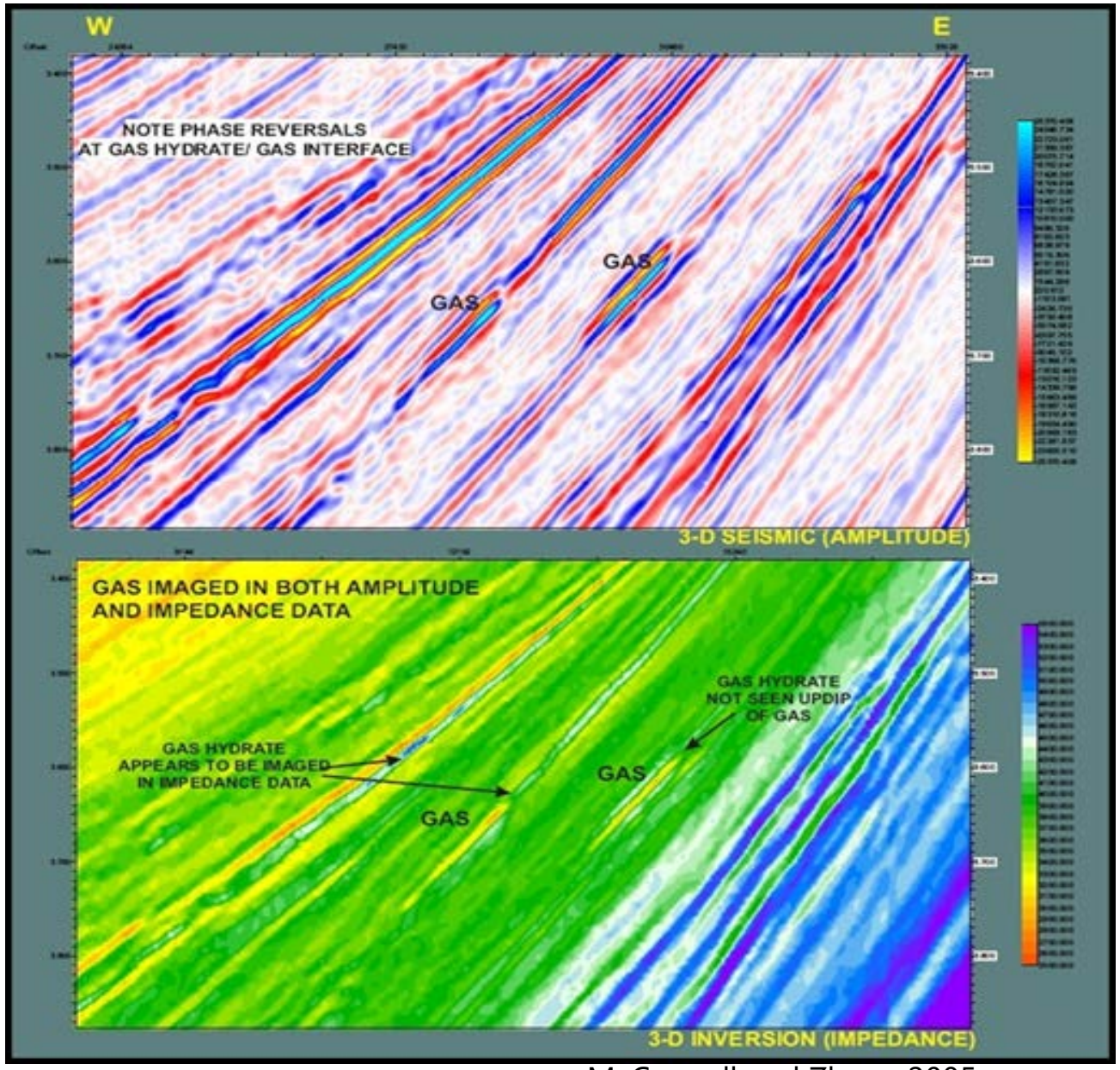


Bg at hydrostatic; 21° C/km; 1500 m water depth; 5 deg

Question for the committee

Have we thought about gas hydrate accommodation?

In deepwater settings like WR 313, we are not concentrating energy in gas hydrates, we are enlarging the space needed for same amount of gas. Is there a mechanism here for how gas hydrate fills the basin floor sands in WR 313?



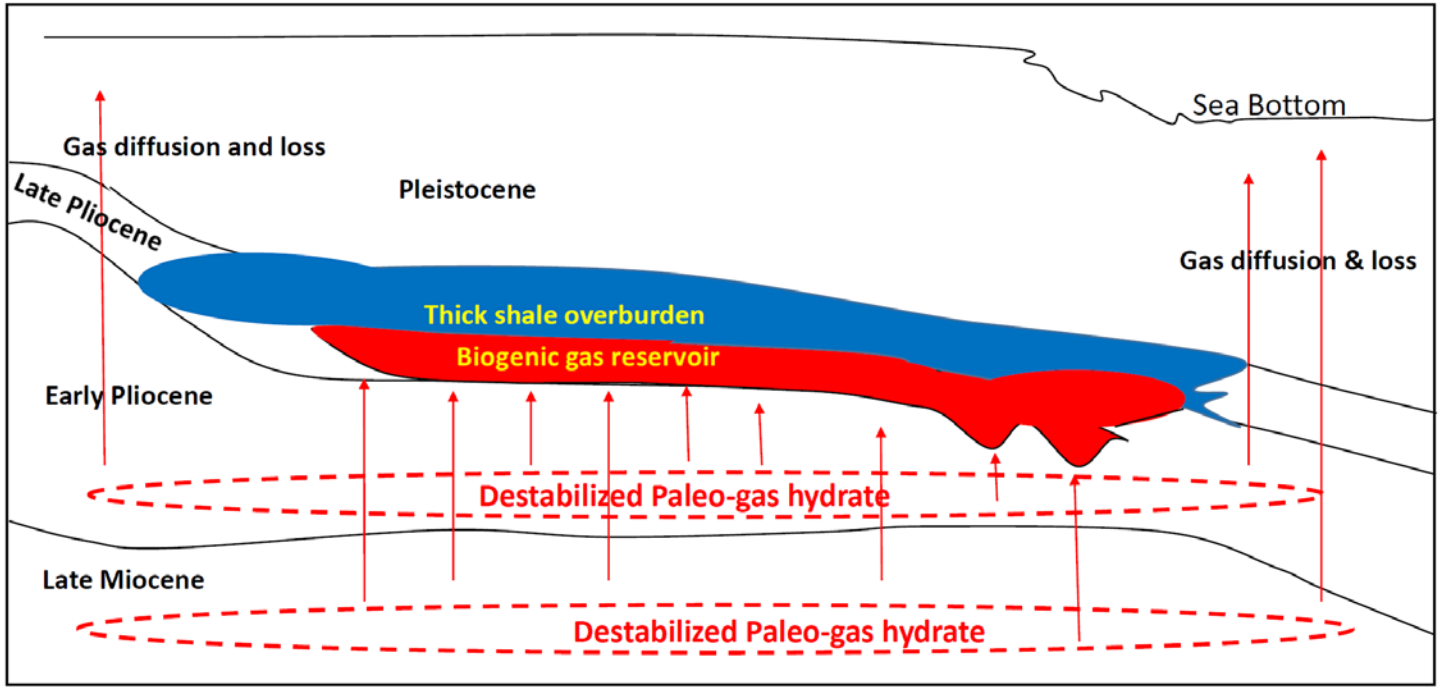
McConnell and Zhang 2005

How do hydrates contribute to biogenic gas plays?

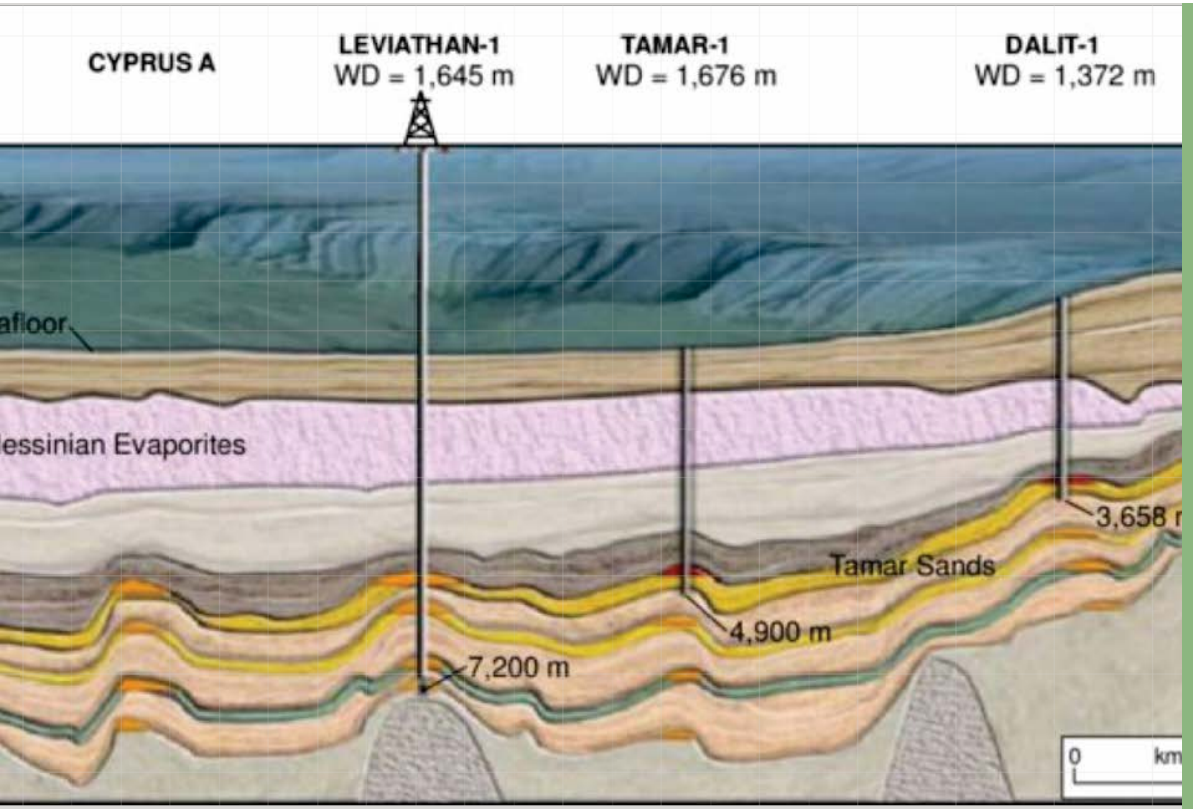
By forming at with lithologic seals themselves

By dissociation and migration

- By increased heat from subsidence or thermal anomaly
  - Recycling
  - Could be stranded
- By reduced pressure e.g. rapid sea level fall



Myint, 2019

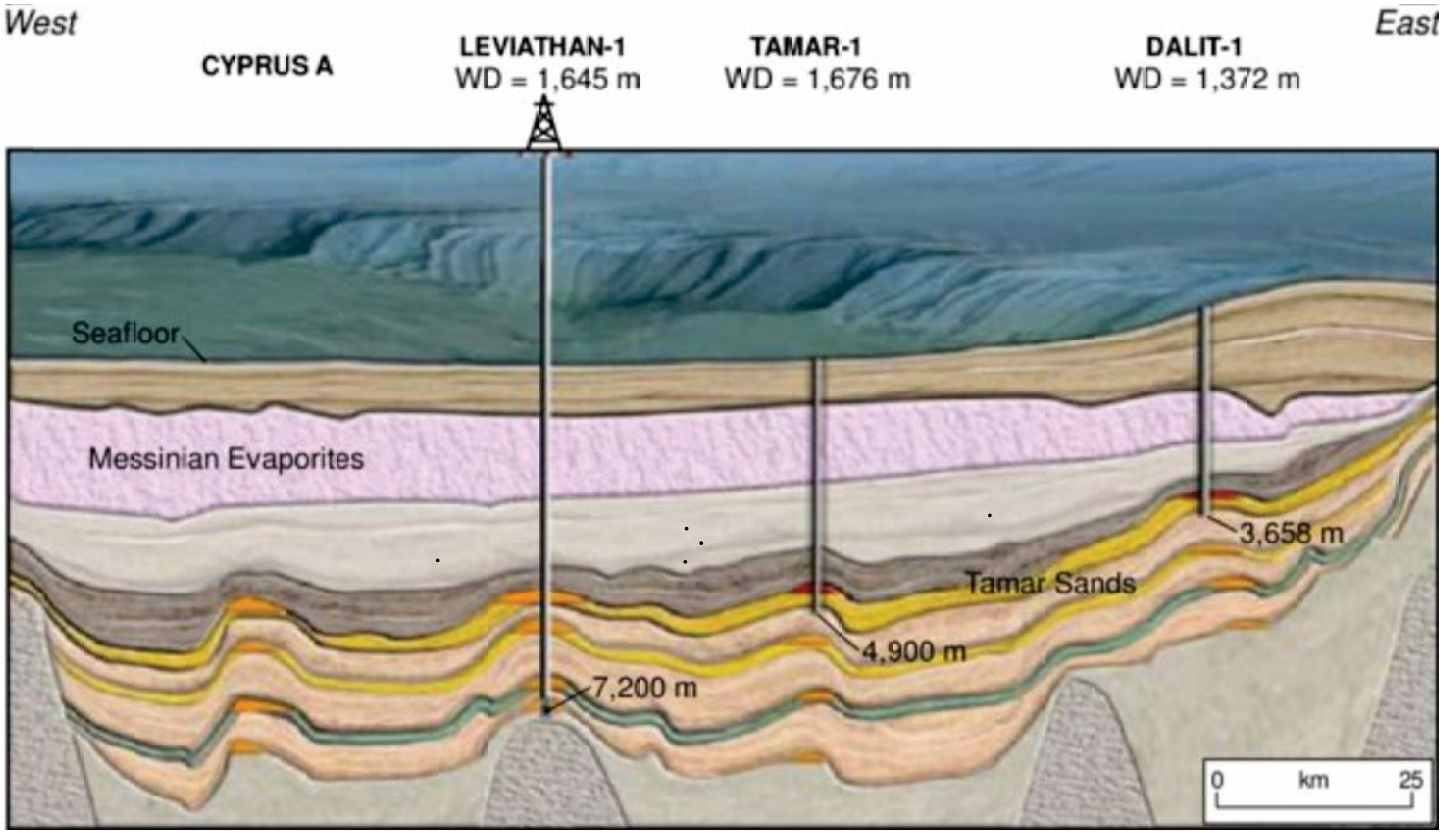


5. Eastern Med example

Eastern Mediterranean

Biogenic gas field that is at temperatures well below the biogenic gas production window

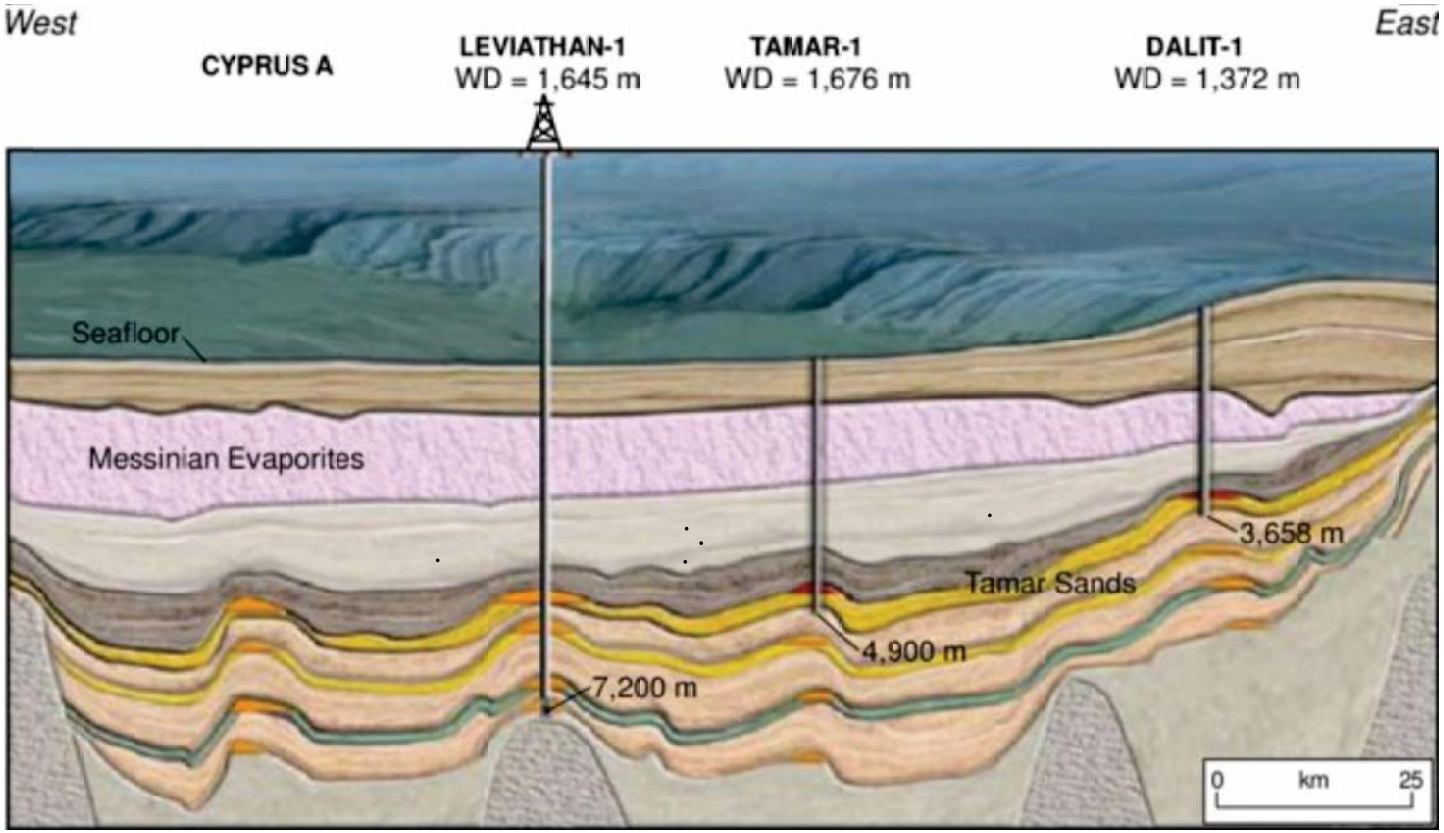
- Reservoir rocks were deposited in deepwater
- The basin would generate and expel biogenic gas. Rapid sedimentation with fetch along existing traps accumulated biogenic traps



Bowman, 2011

Eastern Mediterranean

- Gas hydrates may have had a role in hoteling and concentrating biogenic gas
- Key event was rapid lowering of sea level
- Reduced pressures aids migration from any gas in gas hydrate and aided migration of gas in solution
- The current gas hydrate system is well separated from the gas fields



Bowman, 2011

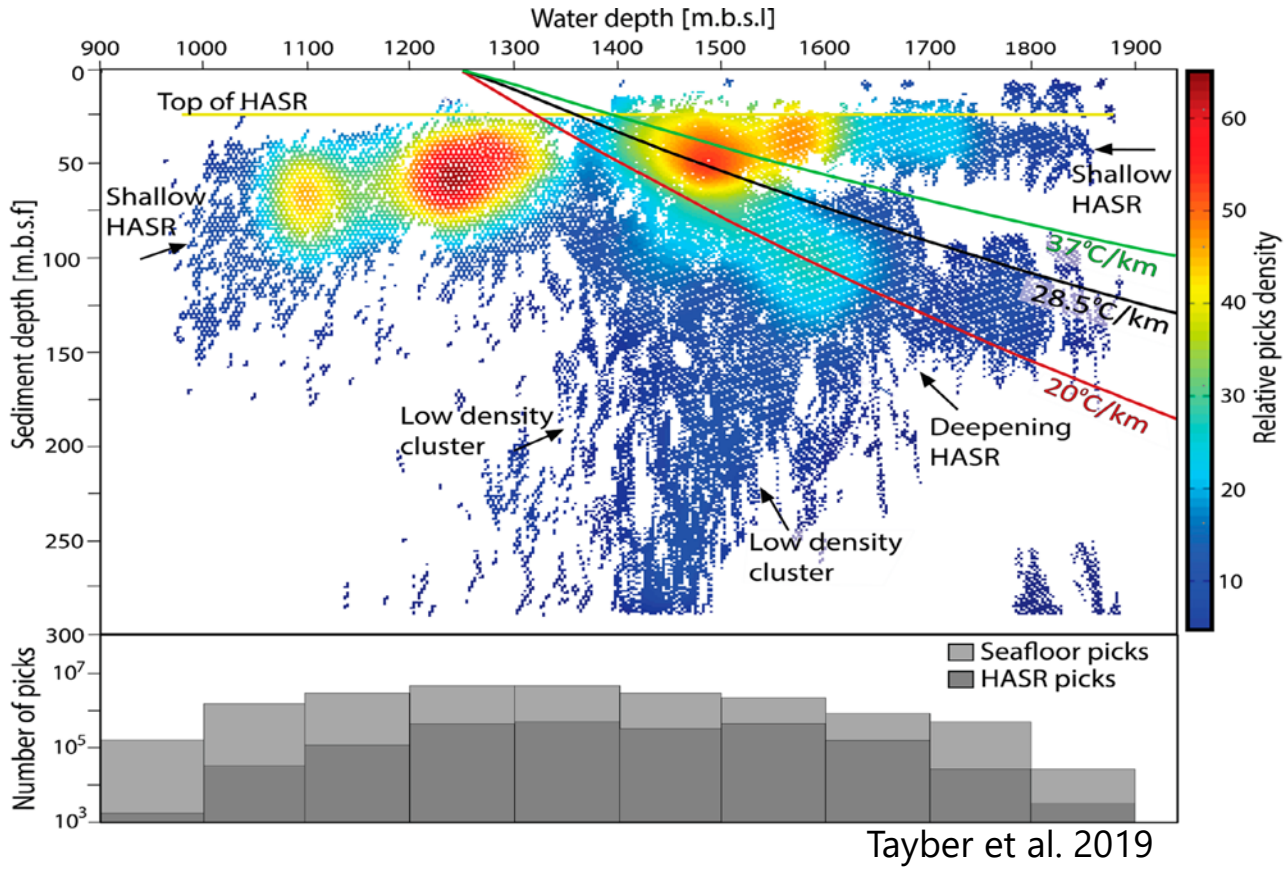
Eastern Mediterranean – current gas hydrate system.

There is a gas hydrate system in the Eastern Mediterranean in the Plio-Pleistocene.

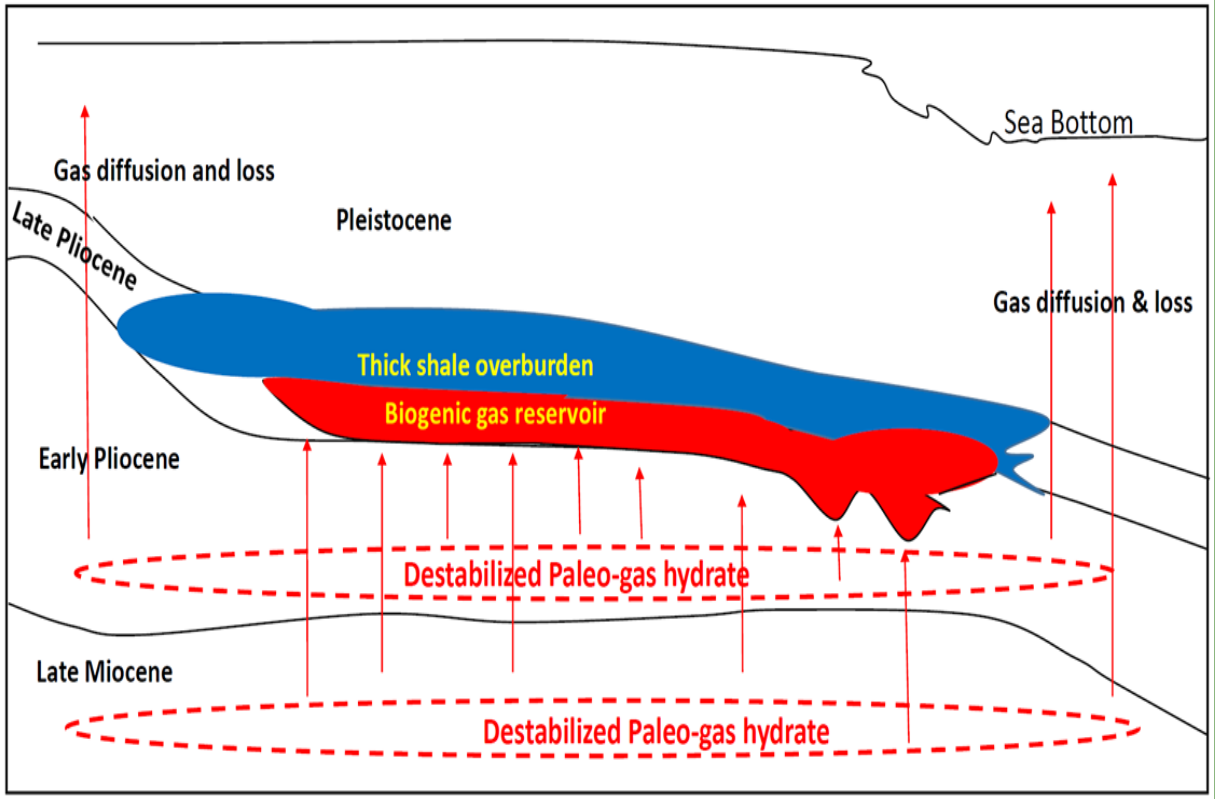
Automatic picks of high amplitude reflectors are clustered.

The top of the high amplitude reflectors marks the base of gas hydrate stability

Clusters of high amplitude seismic reflectors in the Eastern Med



Tayber et al. 2019



6. Myanmar example

Large Biogenic Gas Discoveries and Potential Myanmar

Large Ayeyerwaddy Delta and Ganges-Brahmaputra Delta have proven production from very little exploration.

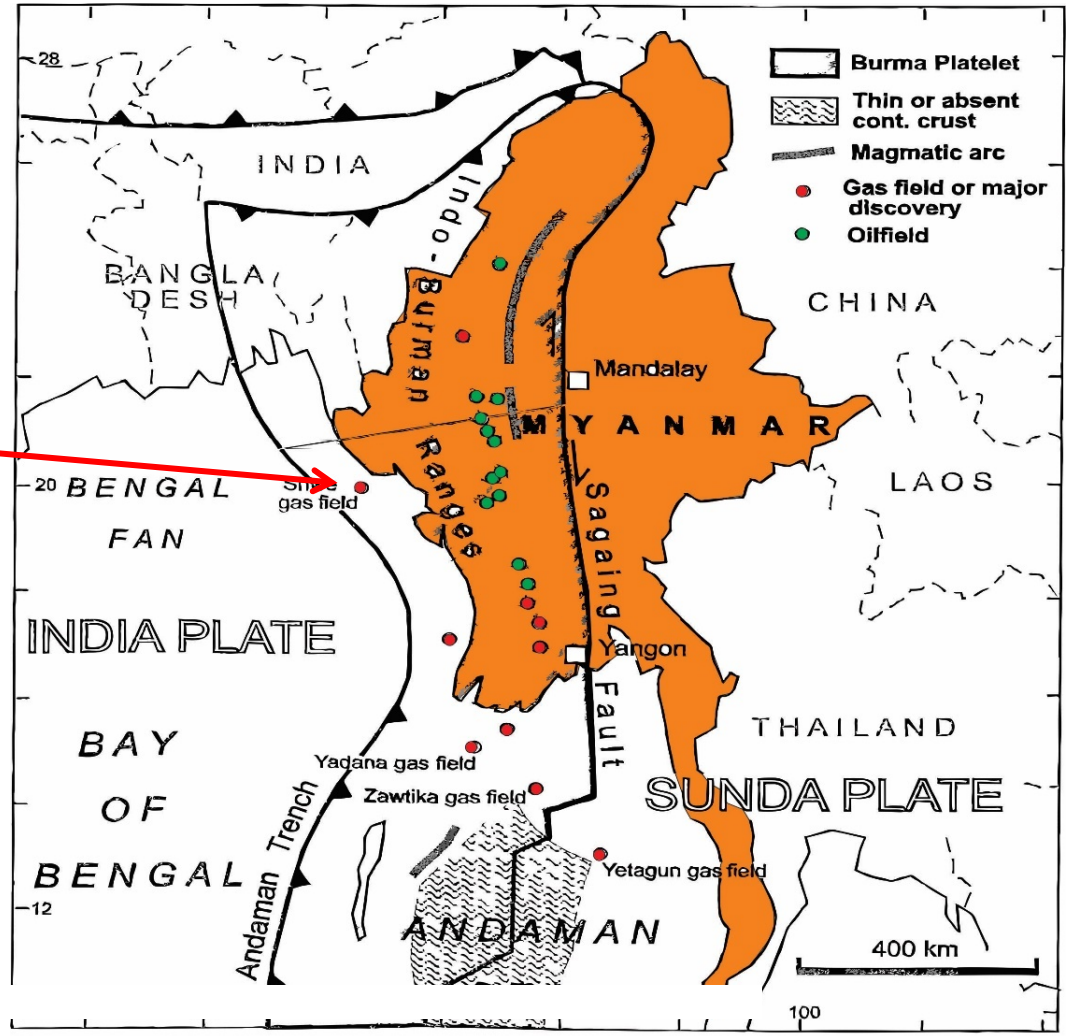
Large multi Tcf Biogenic Gas Discoveries that are being developed.

Shwe gas field is 4.5 tcf

As with many large biogenic gas provinces there is ample evidence for a gas hydrate system in deepwater Myanmar

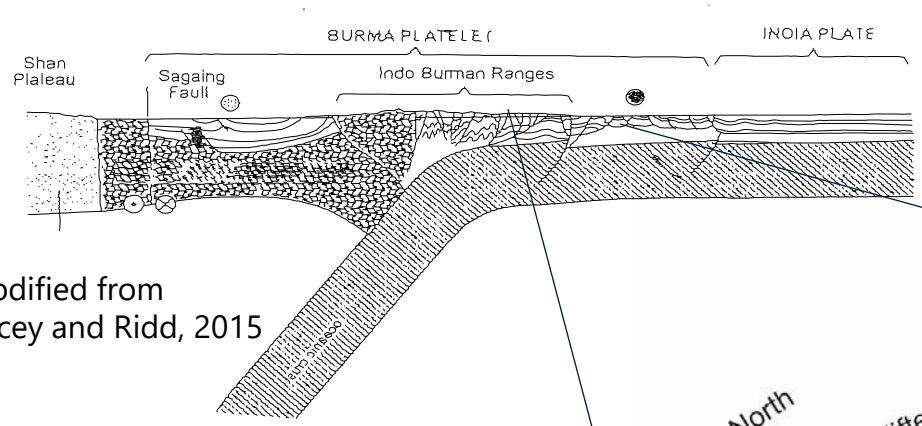
For Gas Hydrate accumulations-
Ample high quality shallow reservoirs

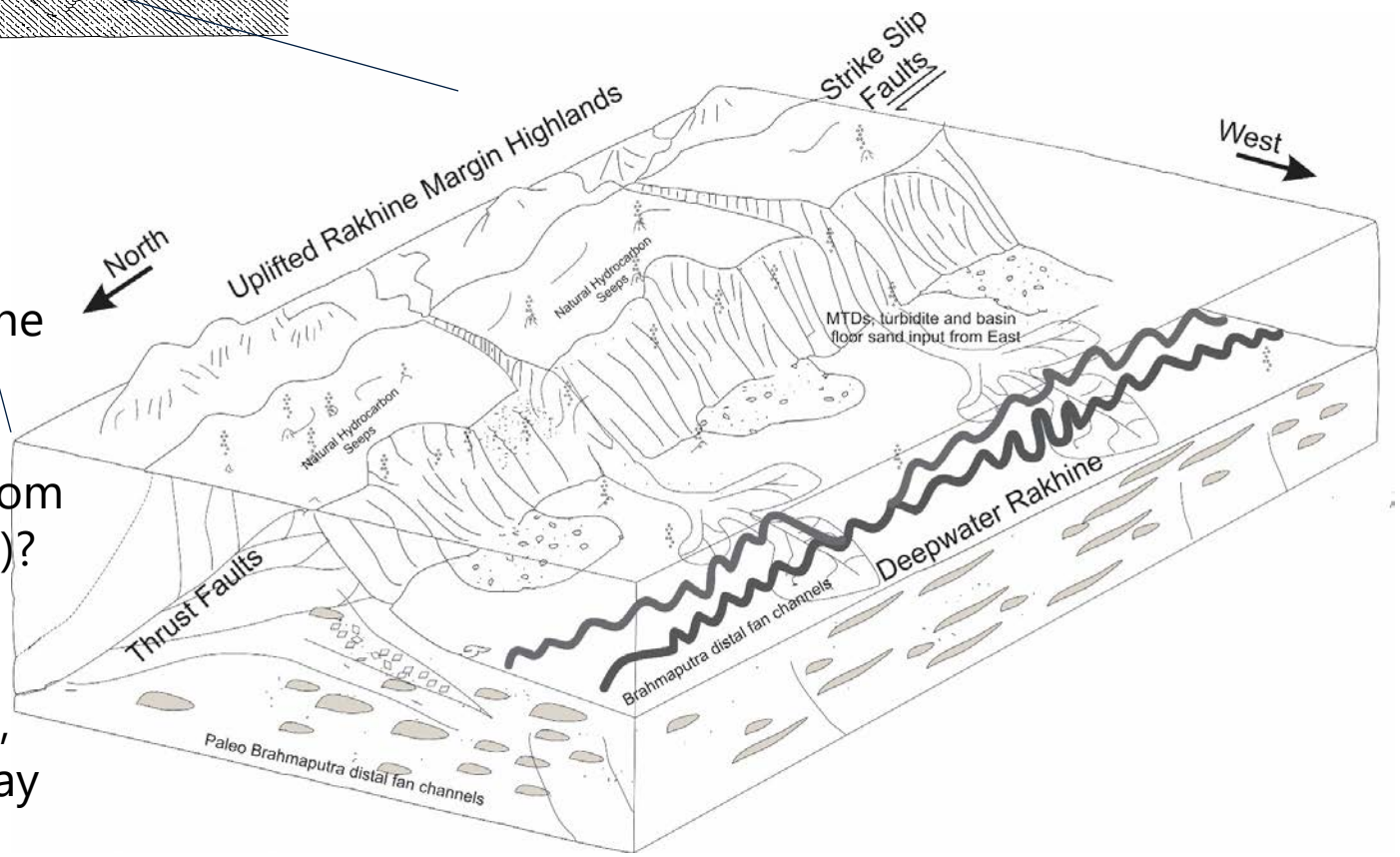
For Deep Biogenic Gas
Challenge is trap, seal, and fetch



Racey and Ridd,2015

Geologic setting in the Rakhine





Pervasive sand reservoirs spanning the base of gas hydrate stability.

Is there a contribution of methane from subducting plate (like Nankai trough)?

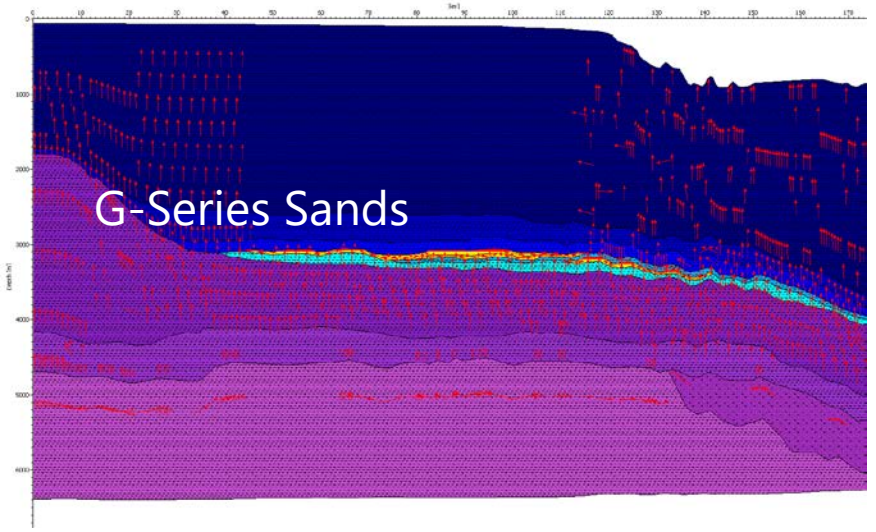
What is known is that microbial methane has been expelled, trapped, and sealed, and that gas hydrates may have had a role.

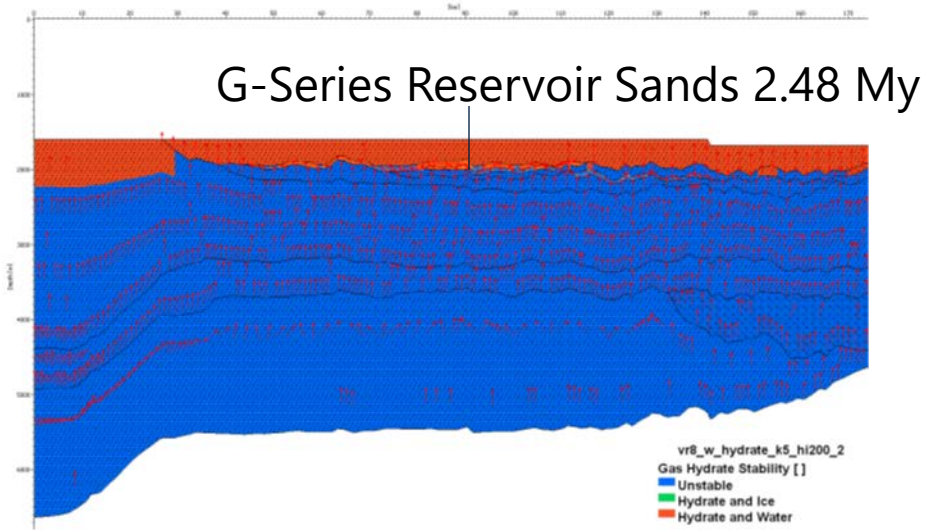
Shwe- Paleo hydrates role in initial trap?

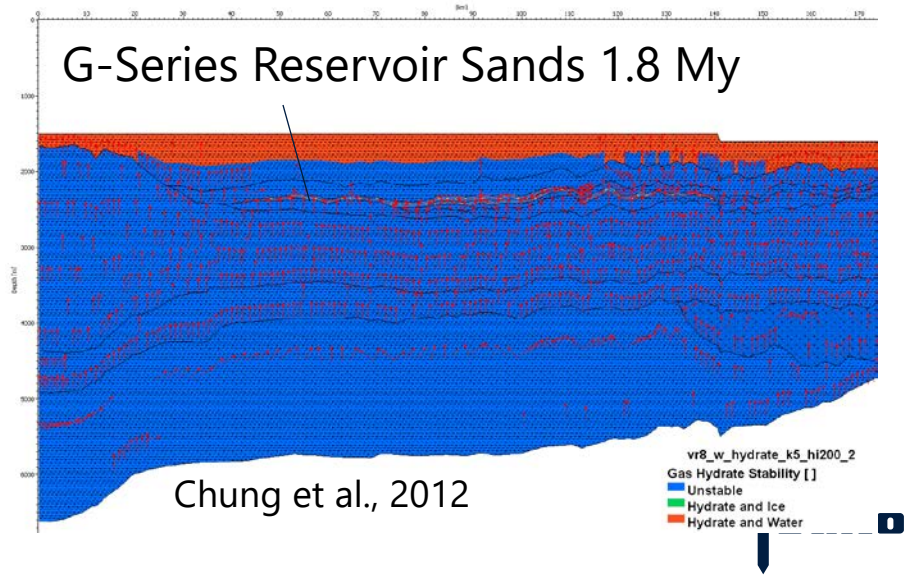
Can gas hydrates have a role in initial trap?

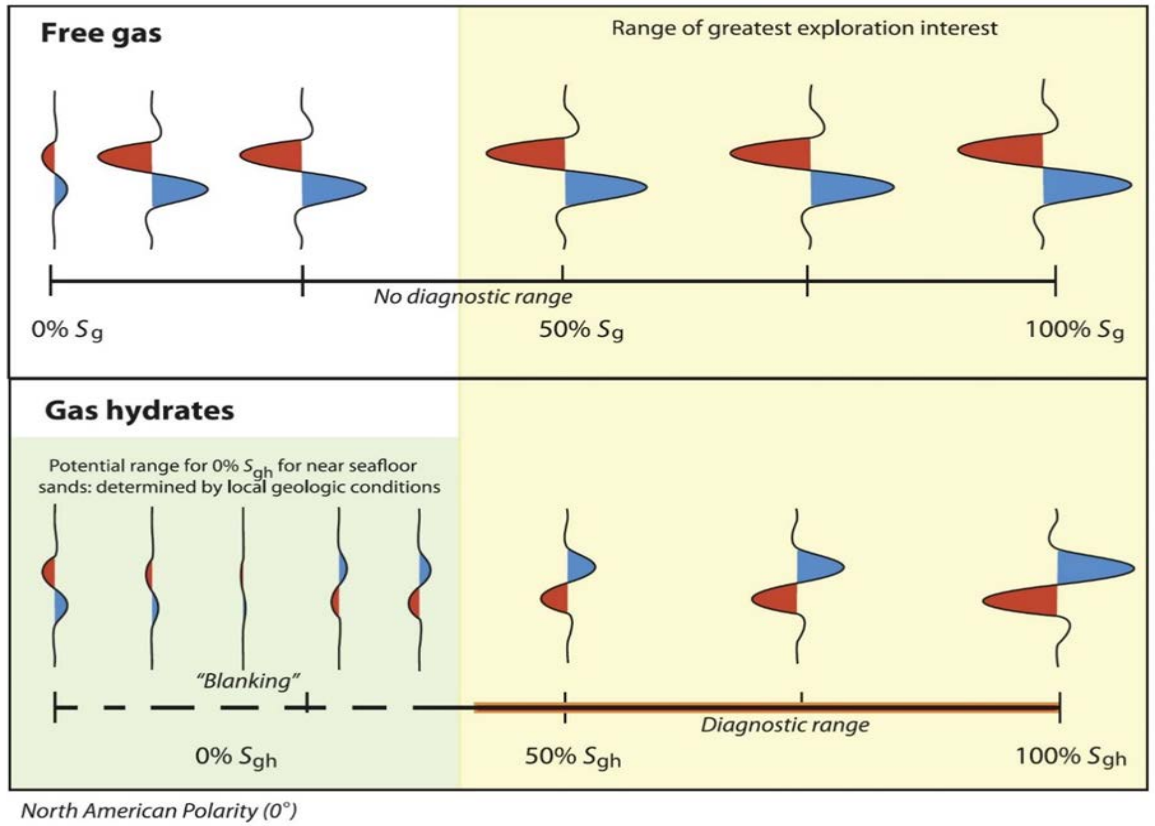
Deepwater “Camden Hills” (MC 348) GoM -Biogenic Gas (in Production) cite Paleo hydrates as the trapping mechanism

Chung et al., show that the in a key gas generation and migration window the Shwe reservoir sands in A-1, A-3 were at the base of gas hydrate stability
Also show a lithologic seal









North American Polarity (0°)

7. Quantifying gas hydrates

Prospecting is similar to conventional oil and gas

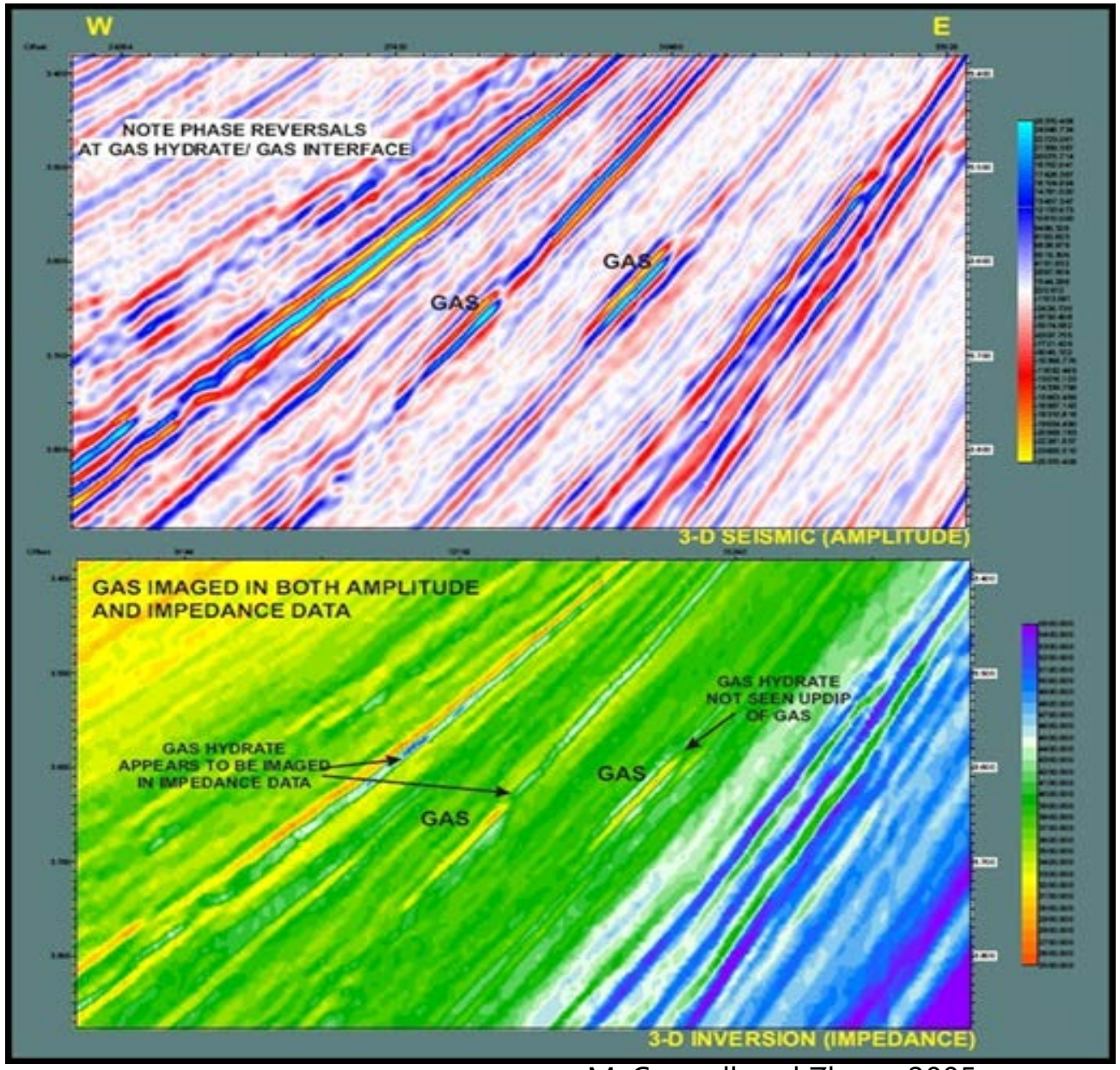
Lithologically contained gas shows as a low impedance- high amplitude event (bright spot)

Map uppermost gassy sediments at the base of gas hydrate stability

A BSR is not necessary

See if the gas sand fills with gas hydrate upon crossing the base of gas hydrate stability (polarity reversal)

Modified oil and gas exploration methods will work. Gas hydrate saturation is related to velocity.



McConnell and Zhang 2005

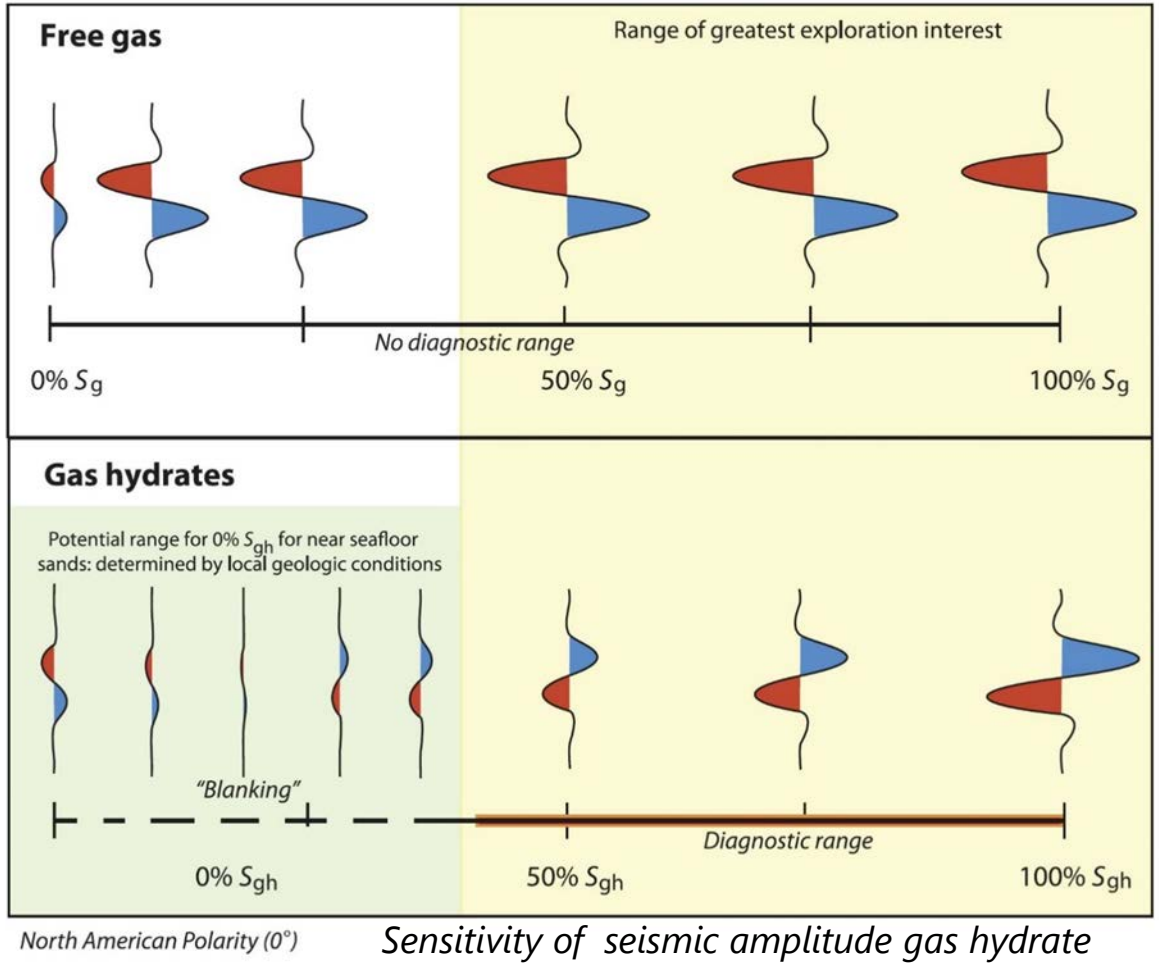
Sensitivity of Amplitude to Gas Hydrate Saturation in Sands

Well known that greater than a 5% saturation gas sand will show as a high amplitude low impedance anomaly.

Amplitude in gas sands is not sensitive to saturation

Gas hydrate saturated sands can be identified by high amplitude high impedance reflectors

Amplitudes in gas hydrate sands appear to be sensitive to saturation.



Sensitivity of seismic amplitude gas hydrate saturation. From Boswell et al., 2016

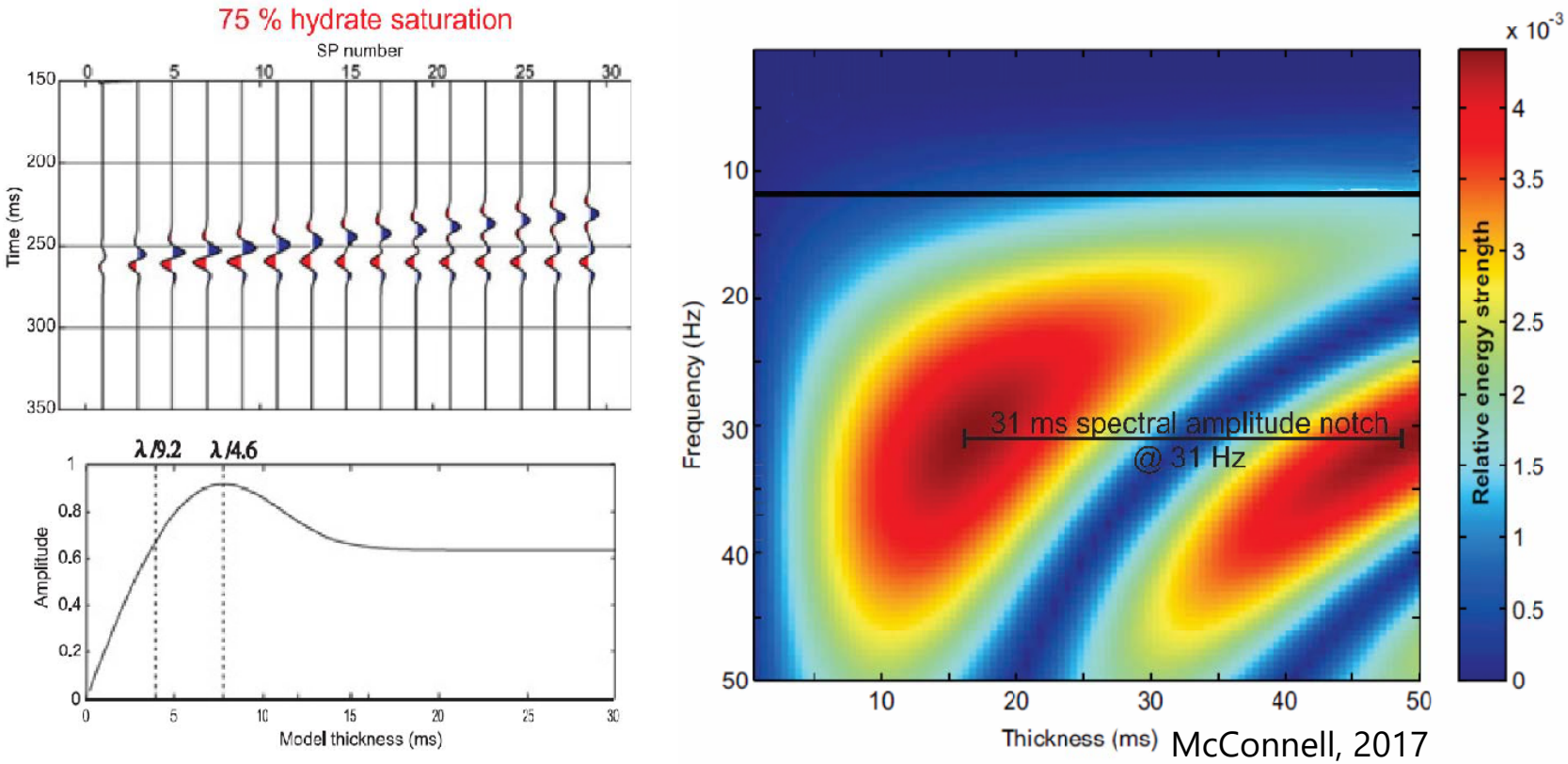
Quantifying gas hydrates- GC 955 H

Example Using the Wedge Model:

Amplitude spectra for the 75% gas hydrate saturation model derived from the wedge model at GC 955 H.

Partyka Pf = 1/t

Pf is the period of frequency notching and t equals thin bed thickness in two-way travel time,.



McConnell, 2017

Mean velocity through the entire 350 m sand, both the gas hydrate saturated portion of the sand and the brine portion of the sand is ~1800 m/s.

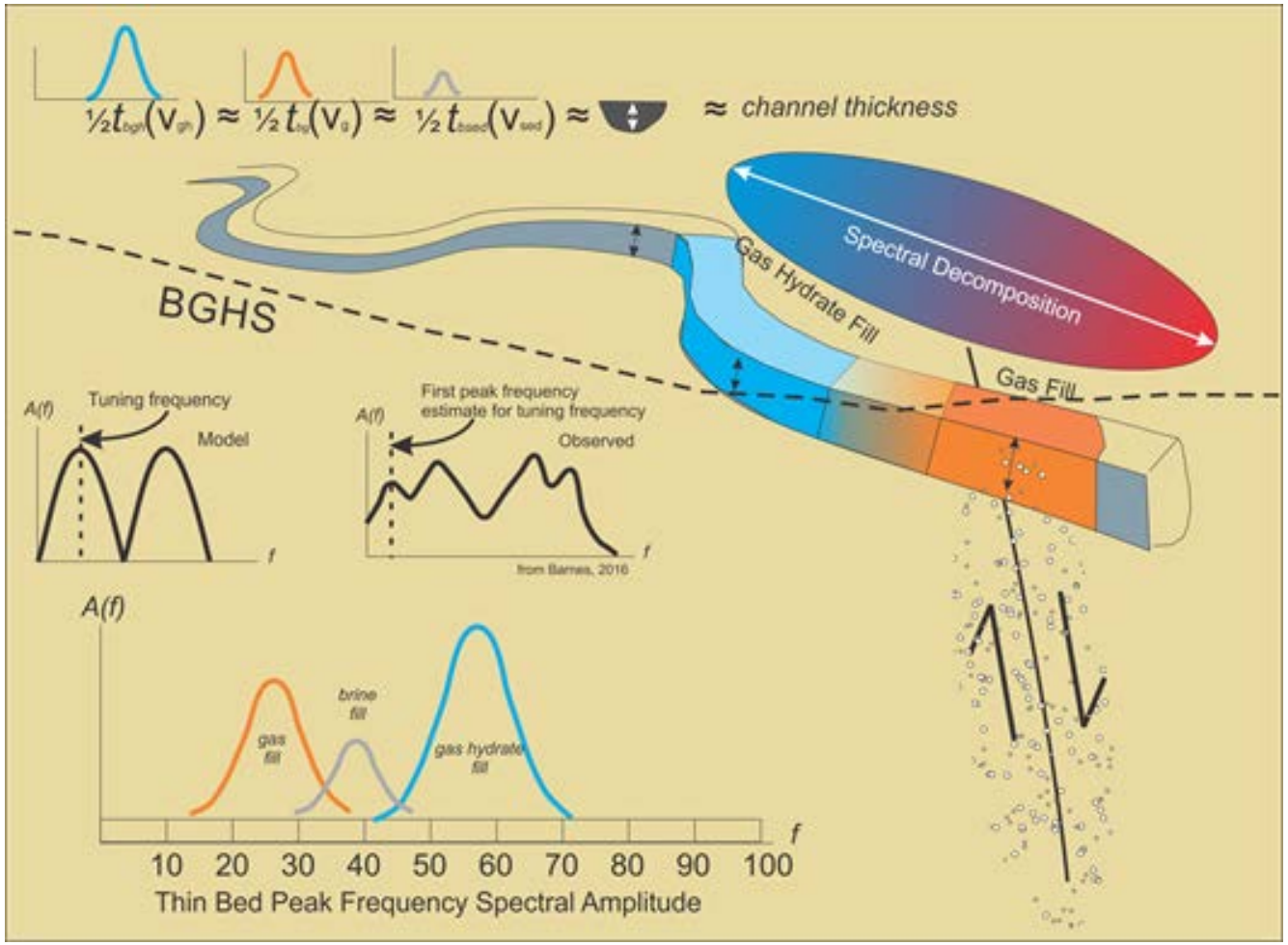
Thin bed thickness from the spectral frequency model wedge is approximately 29 m which is consistent with the 30 m of ~75% saturation gas hydrate sand that was logged at the well

Quantifying gas hydrates

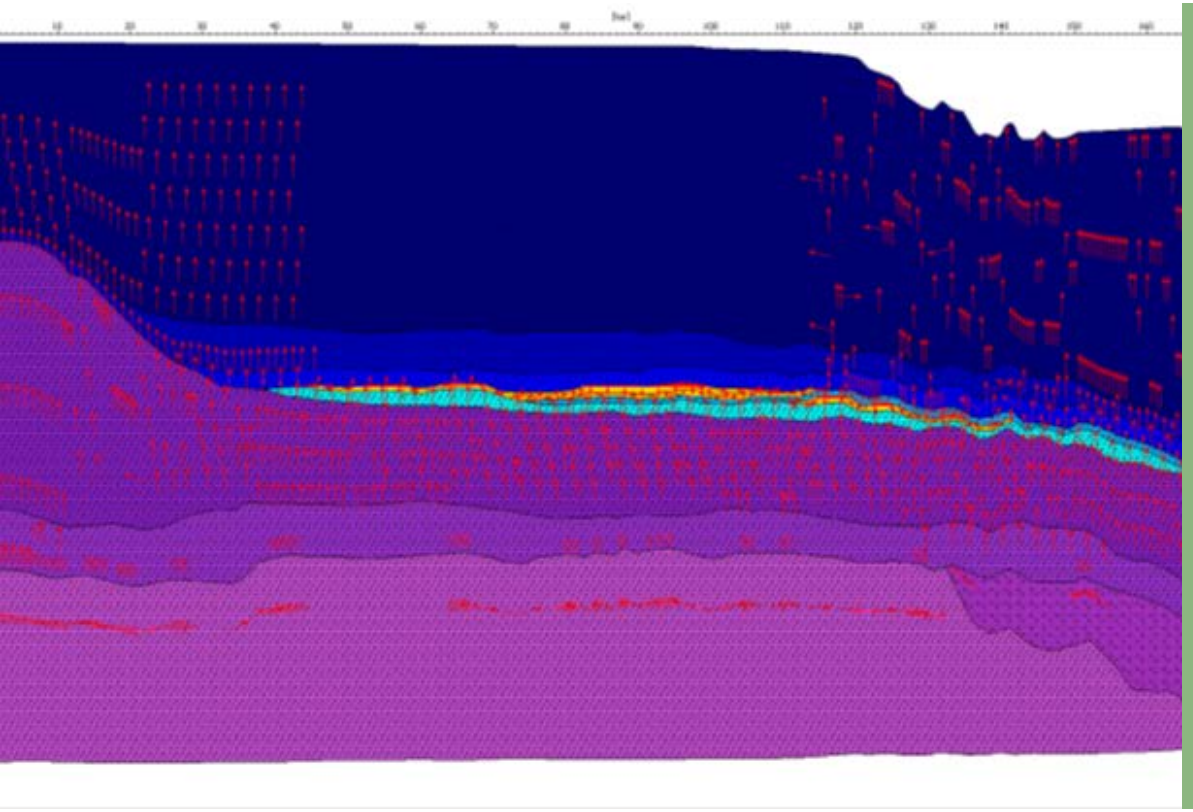
Spectral decomposition is primarily a tool to determine thin bed thickness. Most gas hydrates are thin beds

Because GH make high velocity thin beds it (and other attributes) can be a DHI for gas hydrate

Gas hydrate is thinner in time than the channel with no hydrocarbon charge and the channel is thickest in time where is it gas filled. But, substituting velocities, more likely the channel is same thickness.



McConnell, 2017



8. Summary and conclusions

What can gas hydrate deposits tell us about deeper gas targets and seals?

- Use gas hydrate target as analog to deeper sealing facies.
  - Gas hydrate deposits require sealing facies.
  - The resolution of seismic architecture is enhanced in the shallower part of the deepwater section.
  - Seal sequences that work for gas hydrate may also work for biogenic gas reservoirs at depth.

- Evaluate ongoing biogenic gas generation and migration.
  - Concentrated gas hydrate deposits in sands are visible, analyzable, and unstable
  - Gas hydrate deposits require sealing facies
  - Indicates ongoing generation and migration

Thank you

+1 713 778-6801 T +1 281 630-7835 M

dmcconnell@fugro.com

www.fugro.com