AGU Fall Meeting 2018
Washington, DC

Hydro-mechanical properties of gas hydrate-bearing fine sediments from in-situ testing

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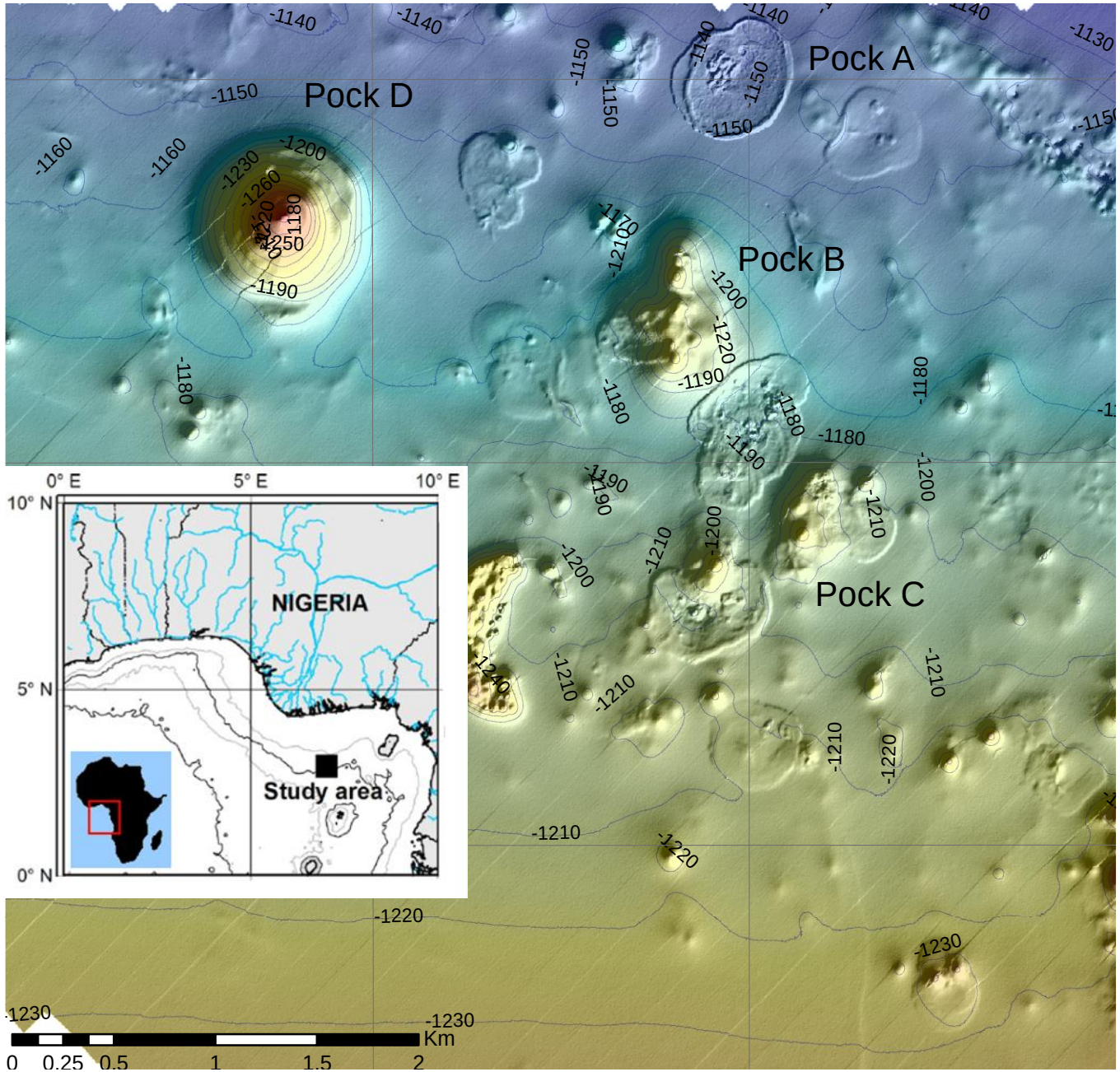
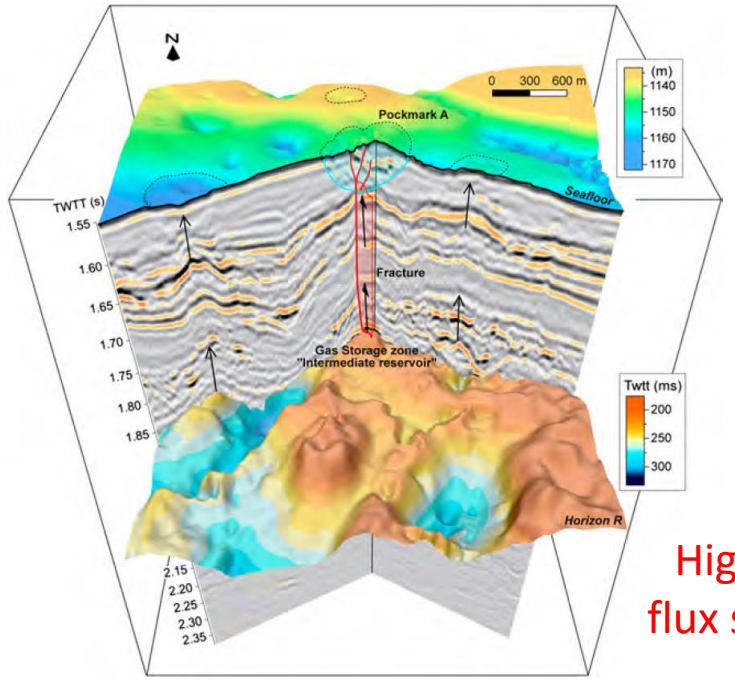
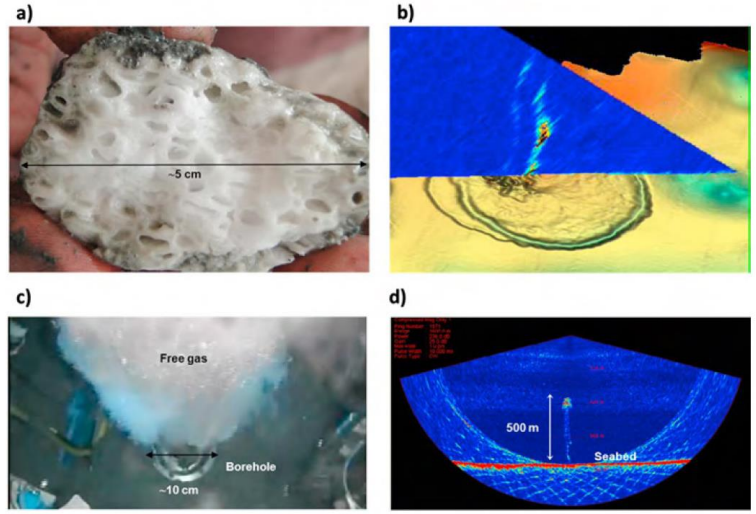
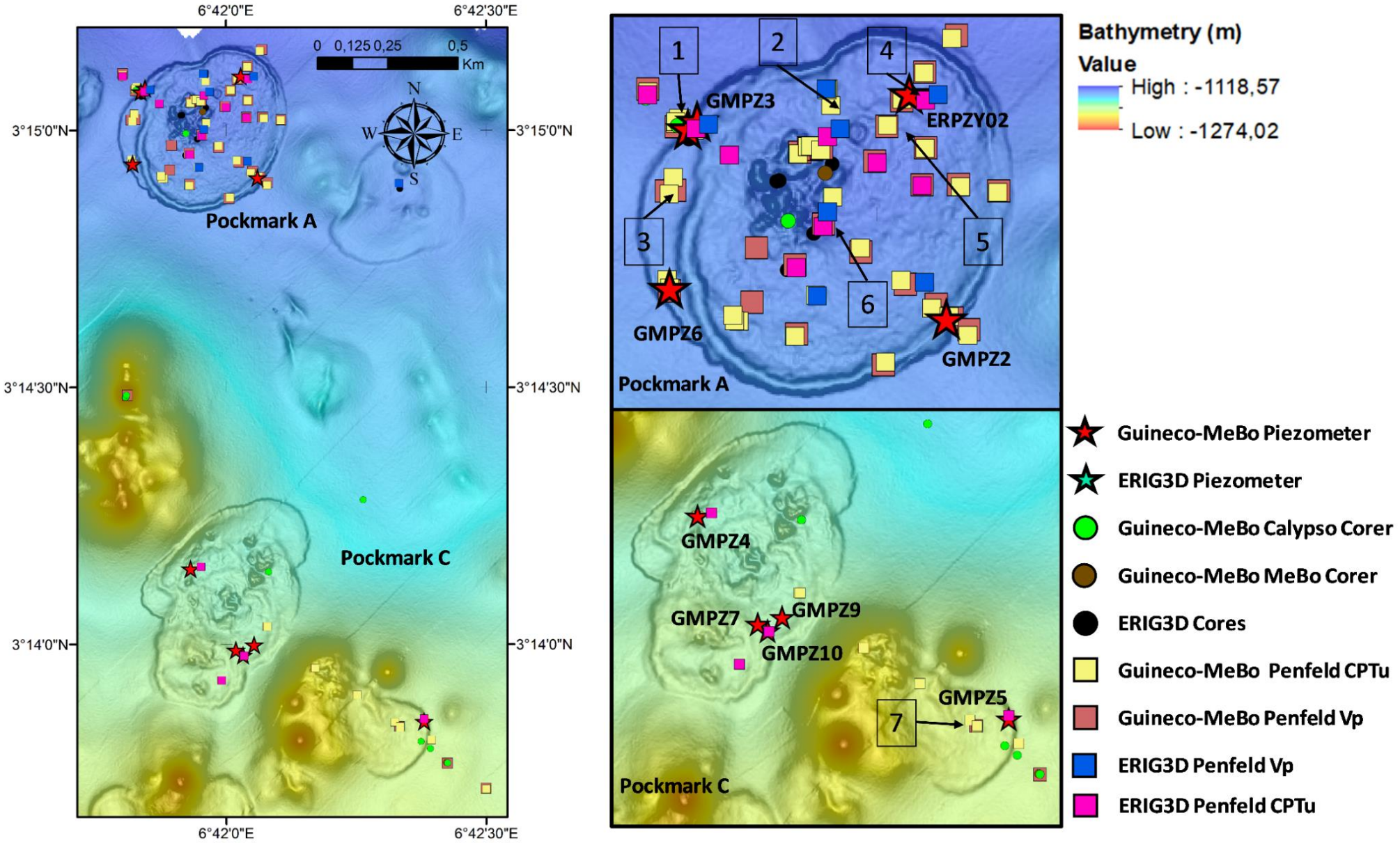




High gas flux system



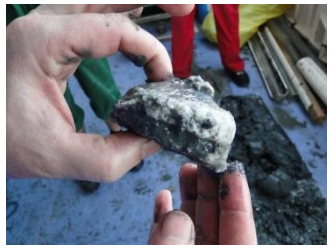
Sultan et al. (2007, 2010, 2014, 2016)
Wei et al., (2015)

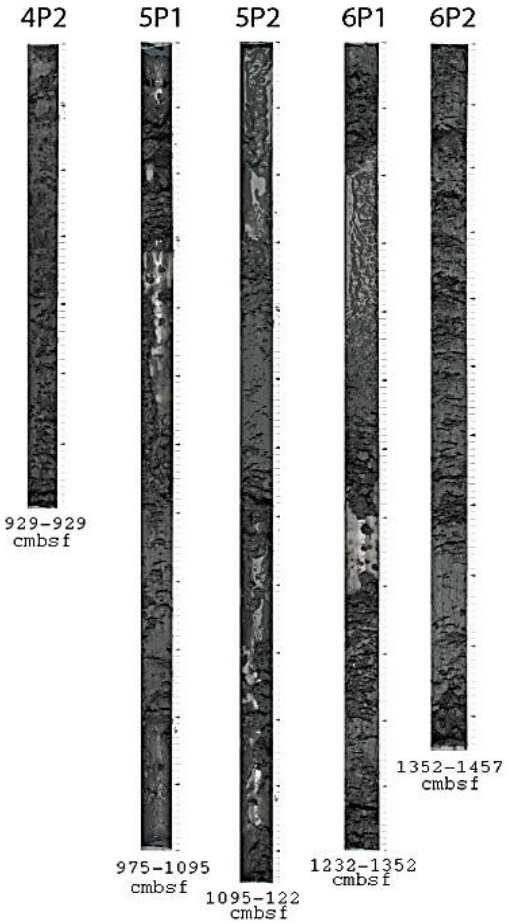

6°42'0"E
6°42'30"E
3°15'0"N
3°14'30"N
3°14'0"N
0 0,125 0,25 0,5 Km
N
W
E
S
Pockmark A
Pockmark C
1
2
3
4
5
6
7
GMPZ3
ERPZY02
GMPZ6
GMPZ2
GMPZ4
GMPZ7
GMPZ9
GMPZ10
GMPZ5
Bathymetry (m)
Value
High : -1118,57
Low : -1274,02
Guineco-MeBo Piezometer
ERIG3D Piezometer
Guineco-MeBo Calypso Corer
Guineco-MeBo MeBo Corer
ERIG3D Cores
Guineco-MeBo Penfeld CPTu
Guineco-MeBo Penfeld Vp
ERIG3D Penfeld Vp
ERIG3D Penfeld CPTu

Coring and Drilling: Sediment Density, Mineralogy and Pore fluid chemistry

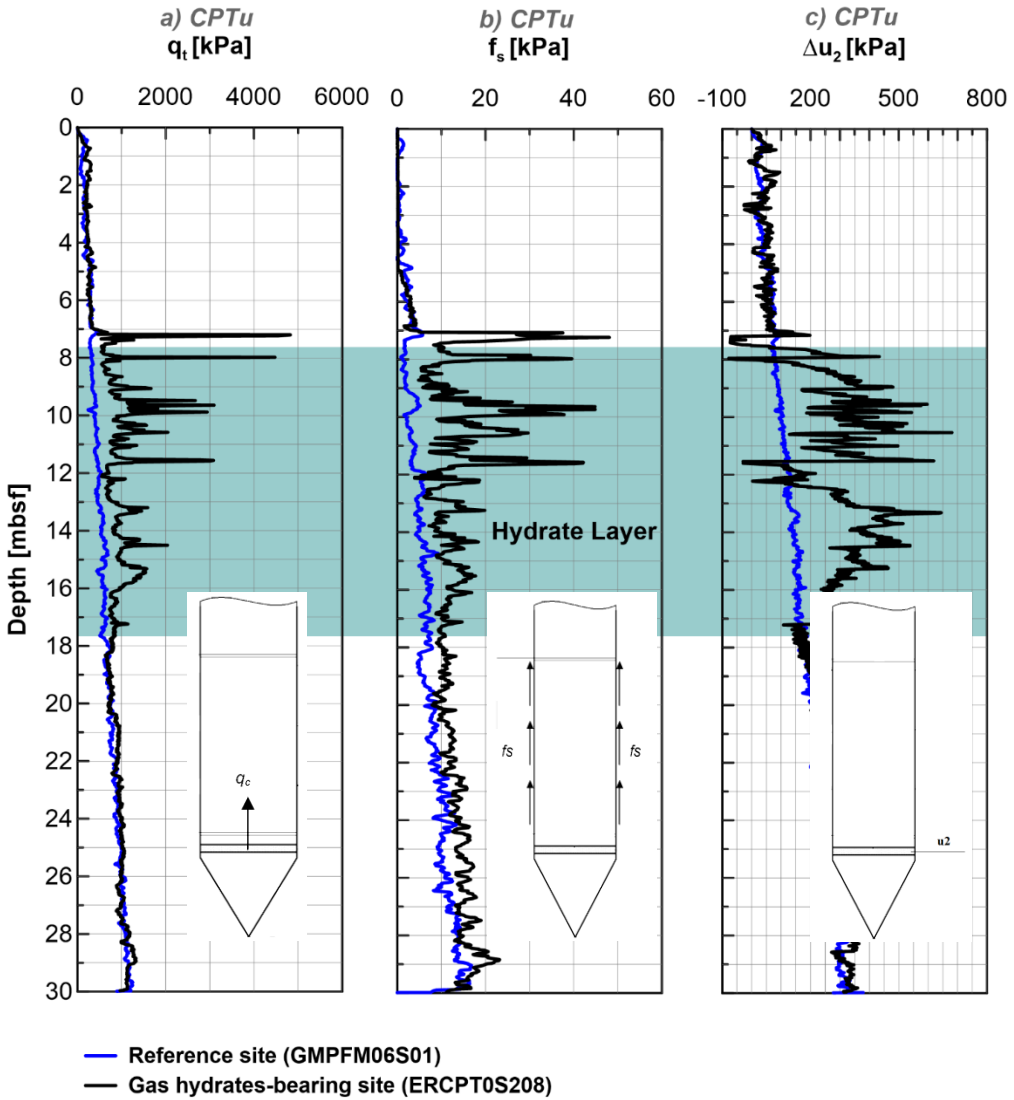
Kullenberg Calypso Corer
(minimal sediment perturbation)

MeBo Corer
(up to 75m of sediment)





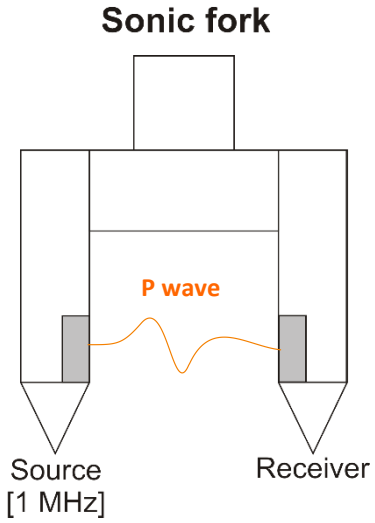
Piezocone sounding: Sediment behaviour classification & Mechanical properties

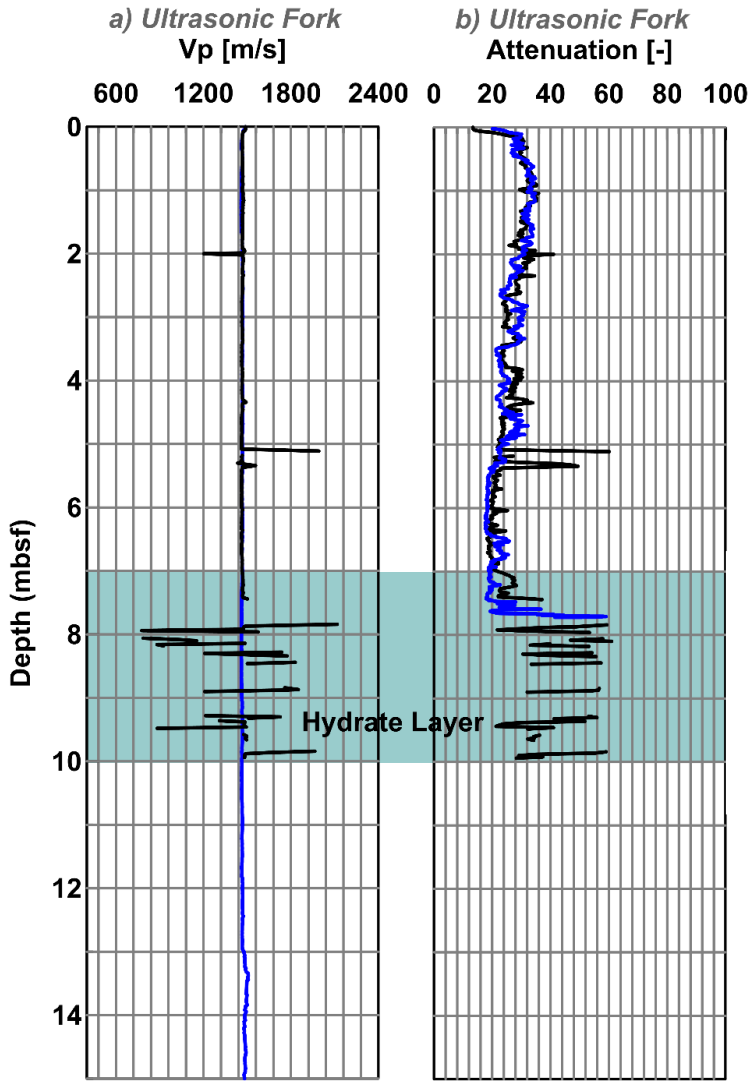


Continuous sounding at a rate of 2cm/s:

- Of 30 m of sediment.
- With a 40 kN thrust.

Acoustic sounding : Gas hydrate detection and quantification

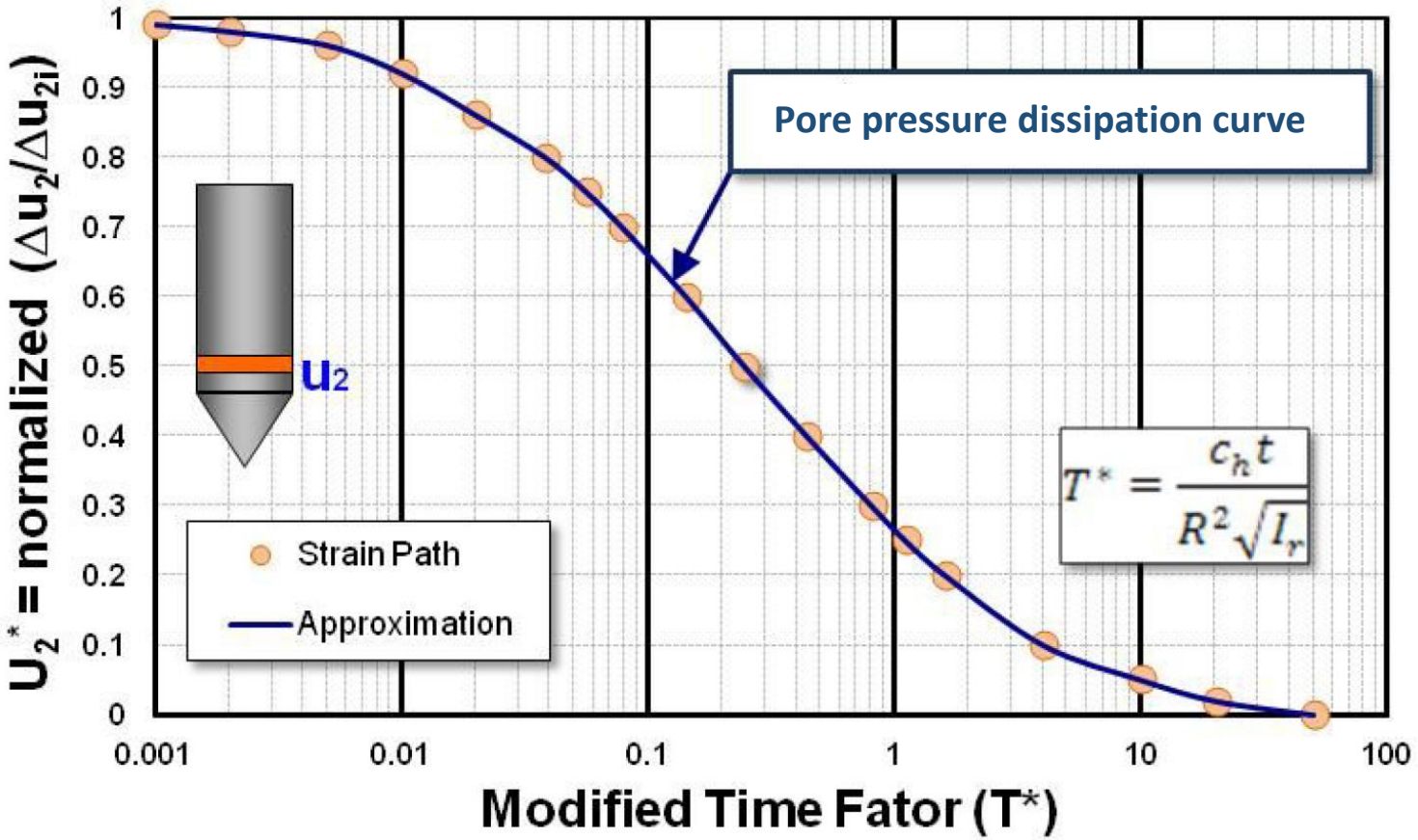




Continuous sounding at a rate of 2cm/s:

- Up to 2200 m/s.
- 1MHz compressional wave.

Pore pressure measurements: Hydraulic properties

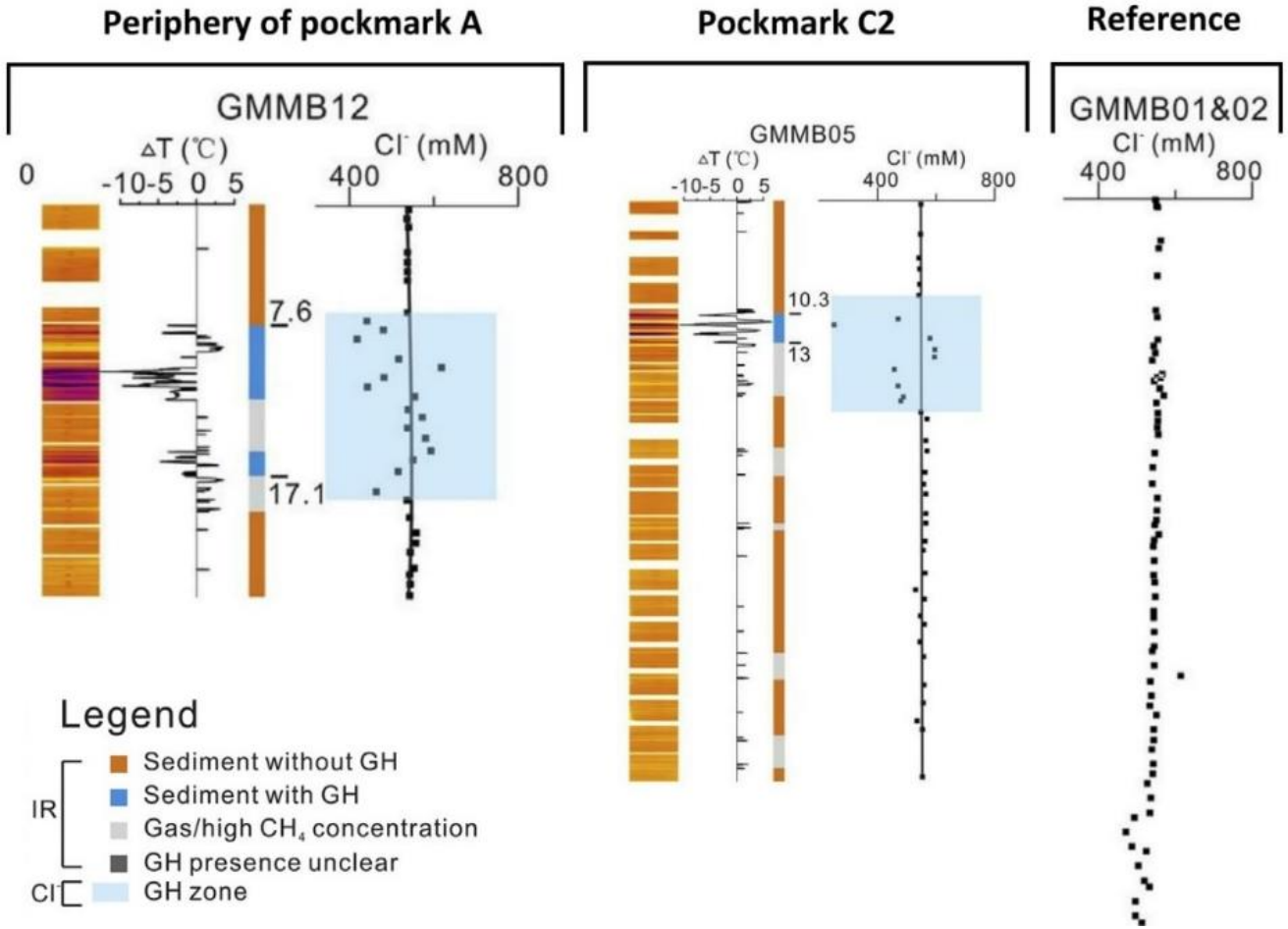


Hydraulic diffusivity: $C_h = \frac{T^*.r^2\sqrt{I_r}}{t_{50}}$

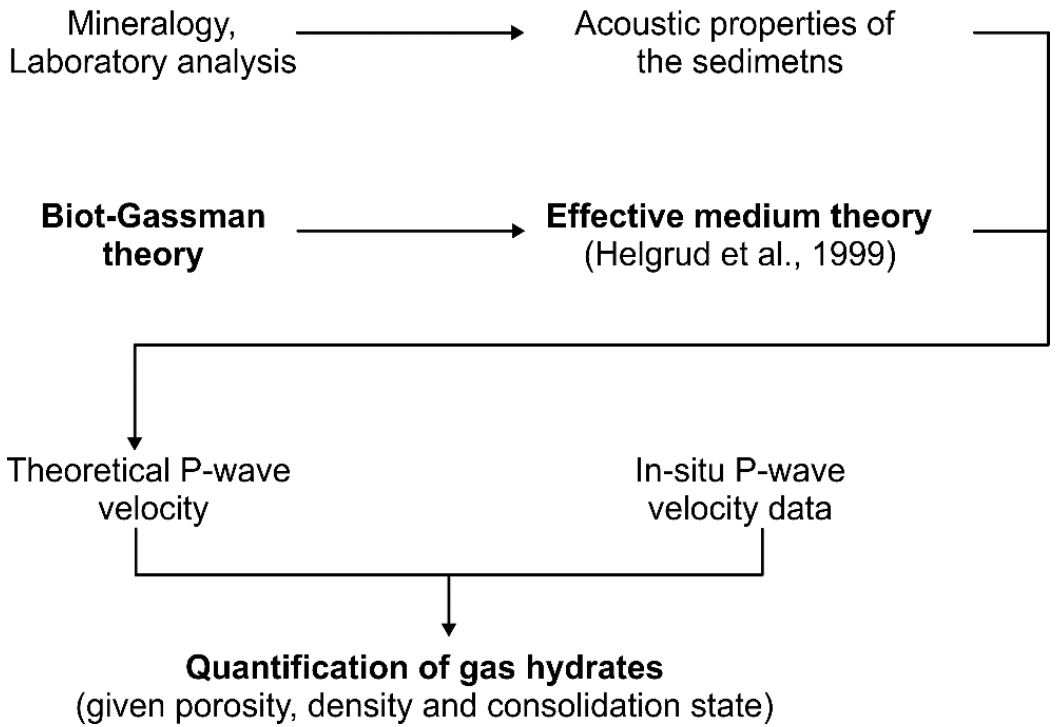
Teh and Houlsby (1991)

Gas Hydrate Quantification methods:

- **Geochemical method** (Malinverno et al., 2008)
  From negative chloride anomalies

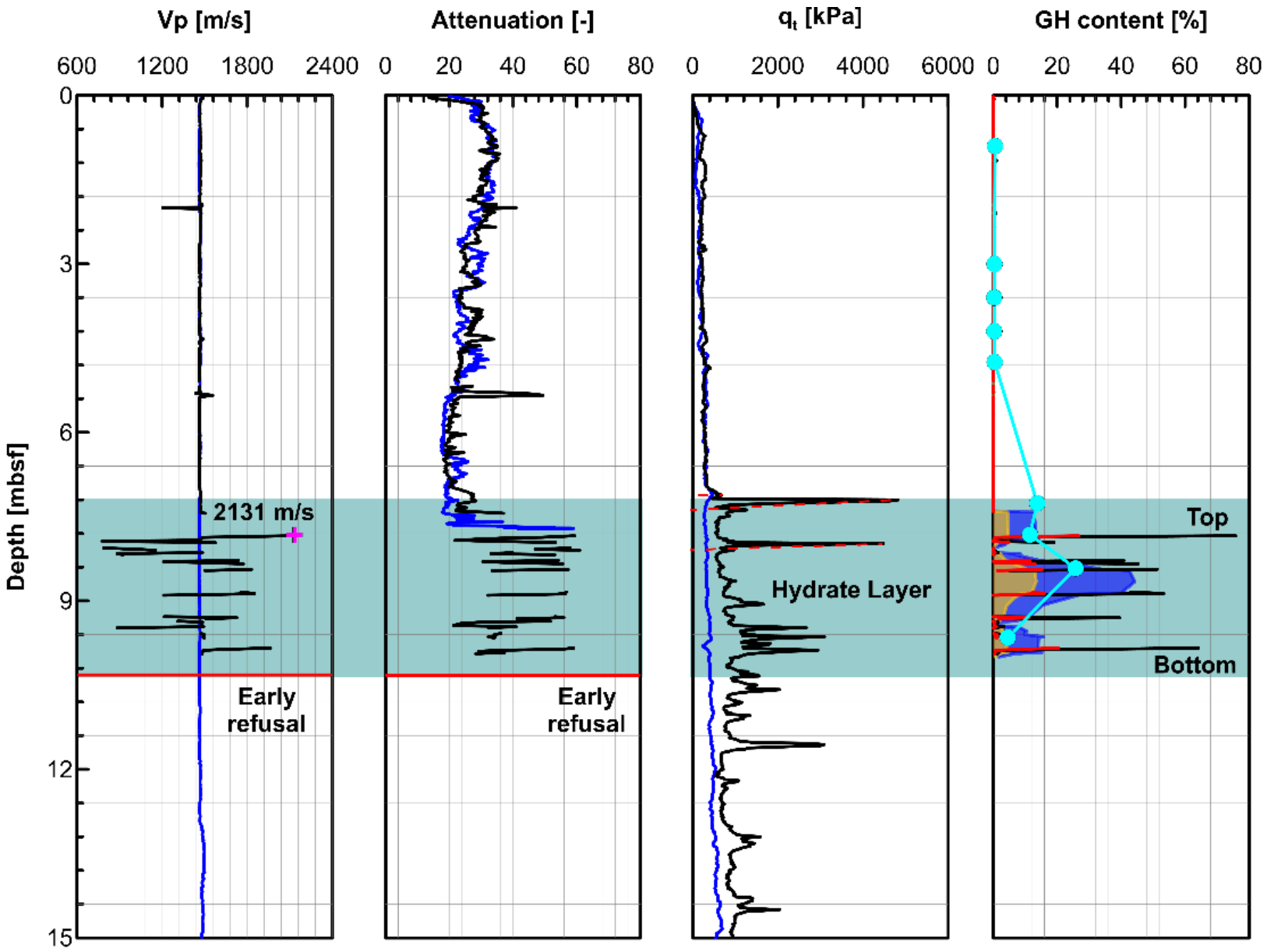


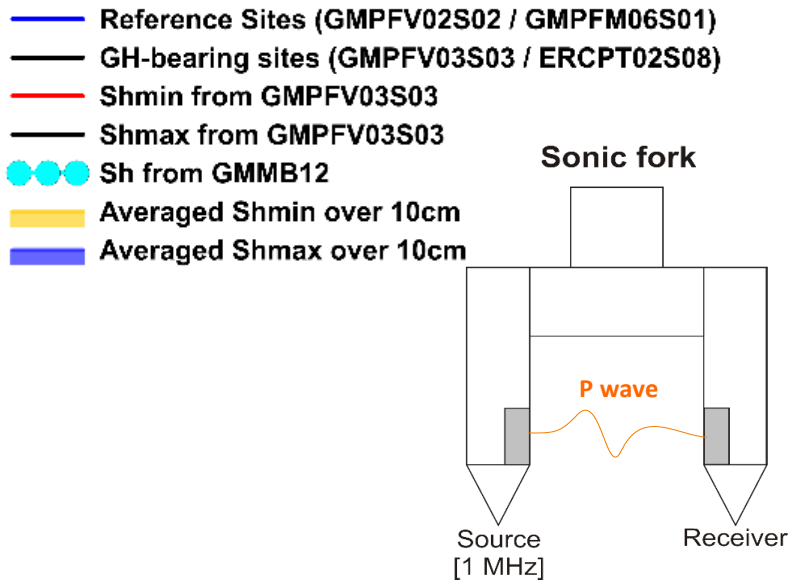
- **Acoustic method (**Helgerud et al., 1999)
  From positive Vp anomalies



Shmin: load-bearing model
Shmax: pore-filling model

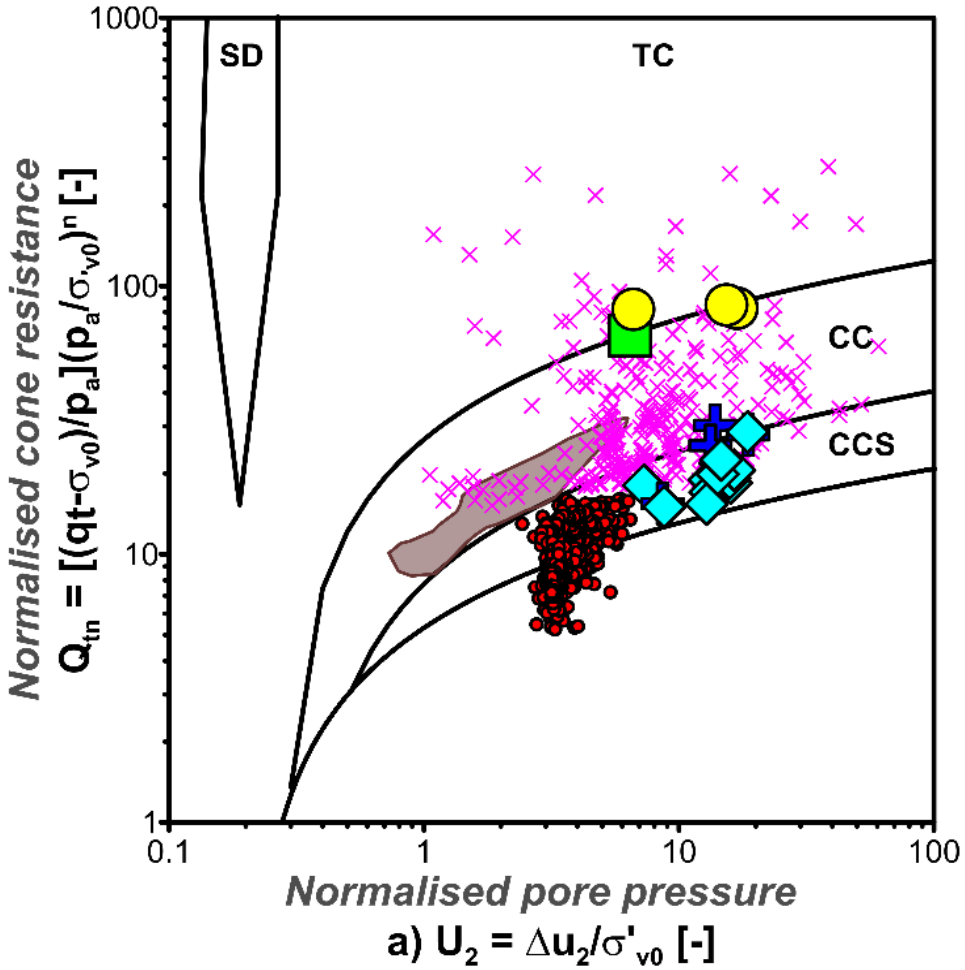
Gas Hydrate Quantification:

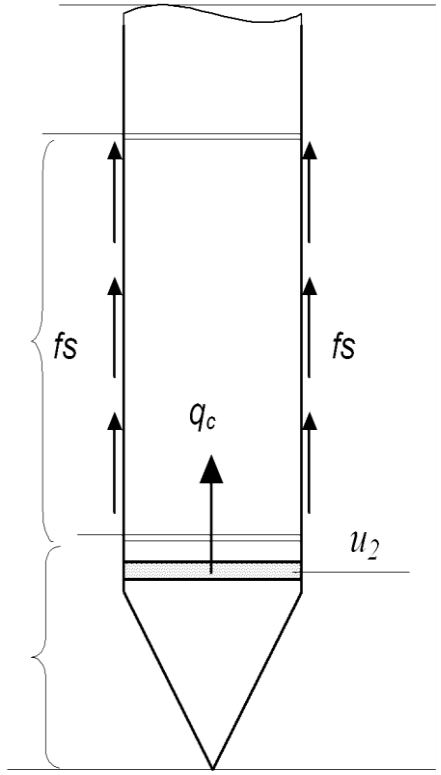




- **Positive Vp anomalies** correlating with increase of geotechnical parameters are indicative of the presence of GH.
- S_h derived from chlorinity anomalies correlate best with Shmin values

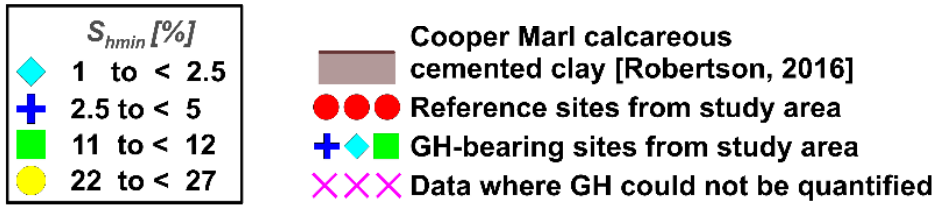
Mechanical behaviour: Classification charts using CPTu and Vp data (Robertson,2016)



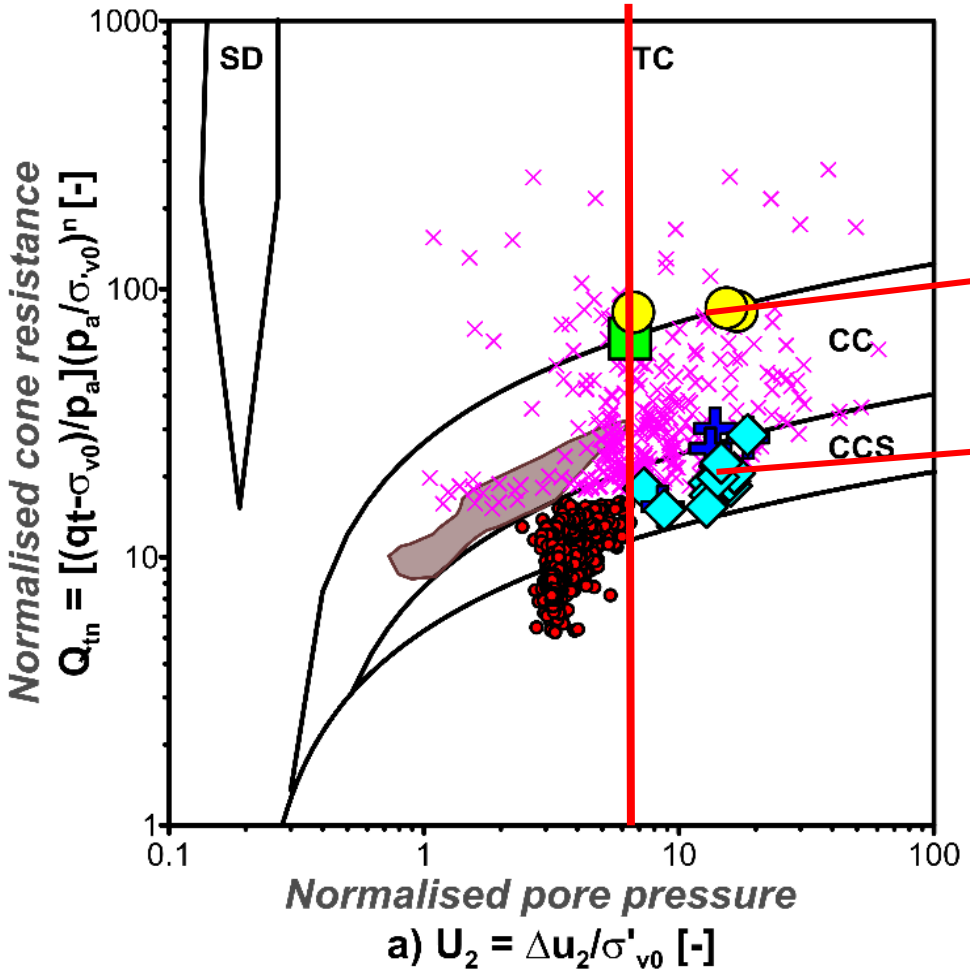


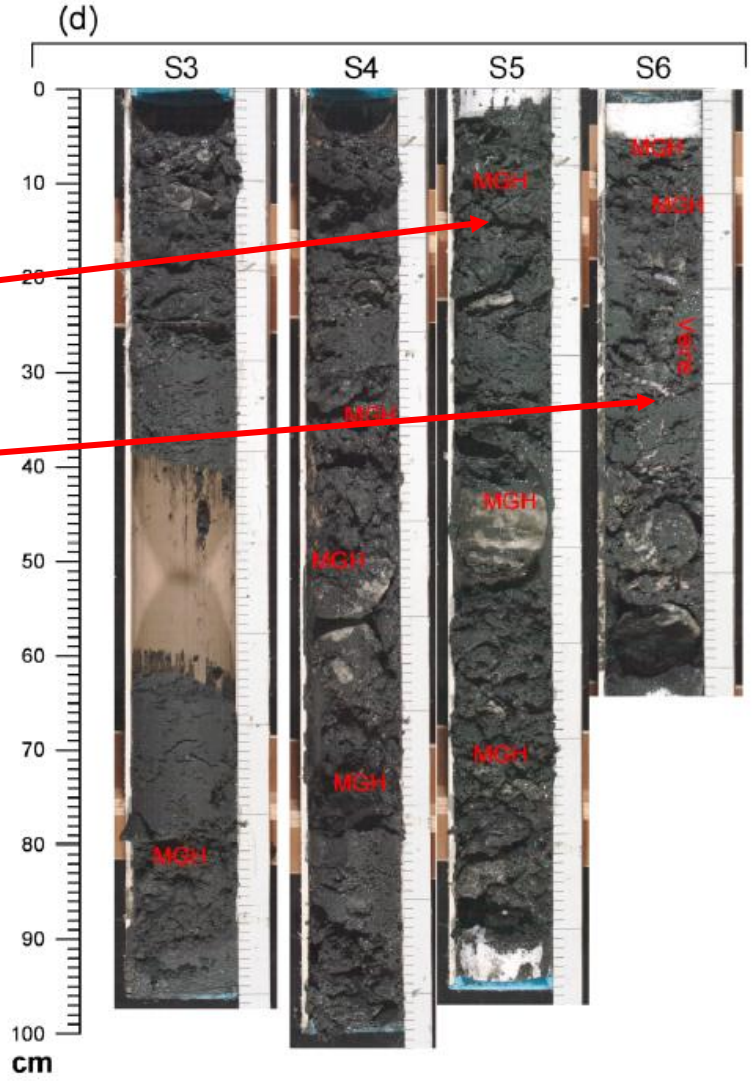
SD: Sand dilative.
SC: Sand contractive.
TD: Transitional dilative.
TC: Transitional contractive.
CD: Clay dilative.
CC: Clay contractive.
CCS: Clay contractive sensitive.

- GH-bearing clayey sediments are characterised by **contractive behaviour**.
- Highest GH content correlates with the highest U_2 and Q_{tn}.
- GH contribute to the increase of the **stiffness and strength** of their host sediment
- The **sensitivity** of GH-bearing sediments does not increase proportionally to their stiffness and strength.



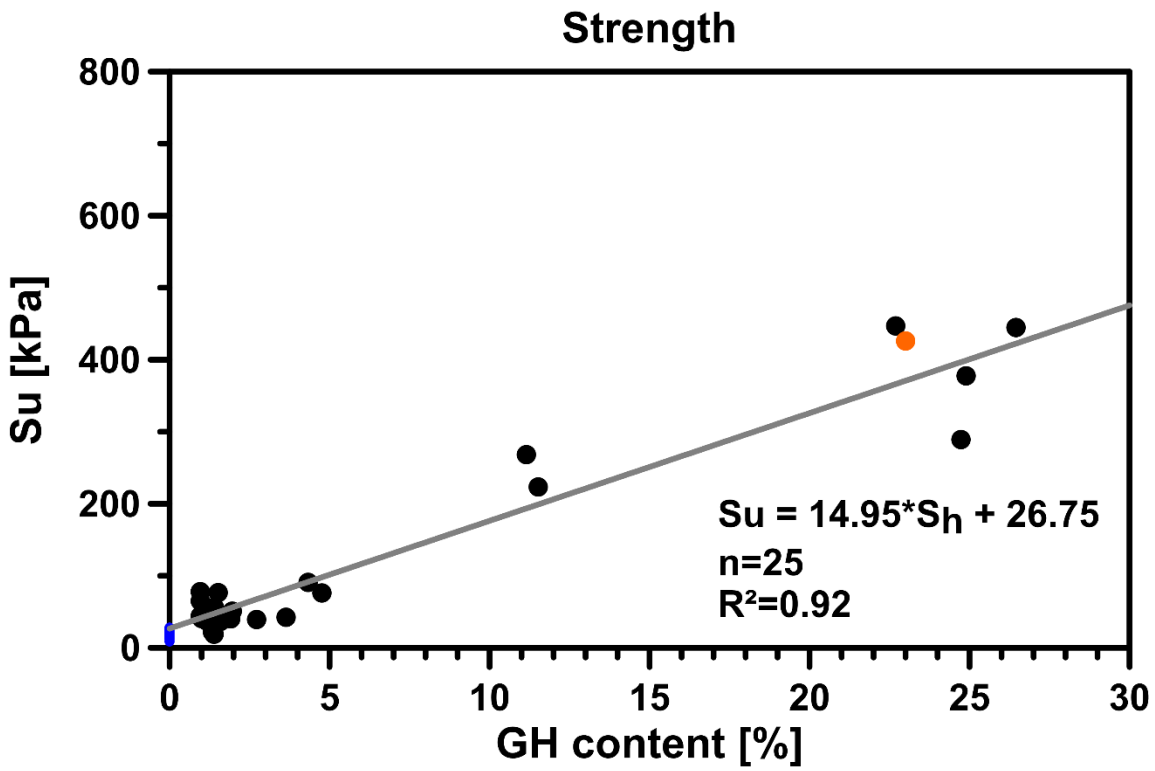
Mechanical behaviour: Classification charts using CPTu and Vp data (Robertson,2016)

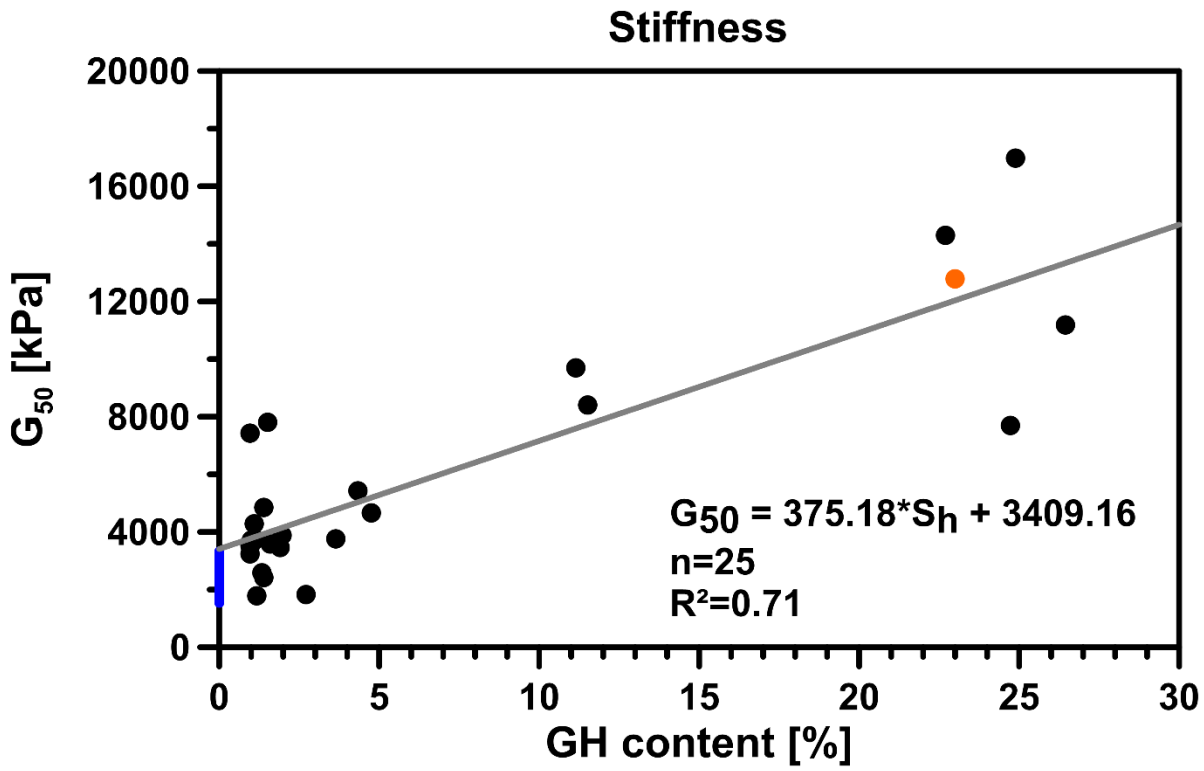




- Visual observations of recovered cores in the study area show GH morphologies varying from groups of millimetre **thick veins to massive nodules**.
- **High GH concentrations** (up to 27%) could be related to the presence of **nodule type hydrate**.
- **Low GH concentrations** (1 to 5%) could be an indicator of the presence of a **group of hydrate veins**.

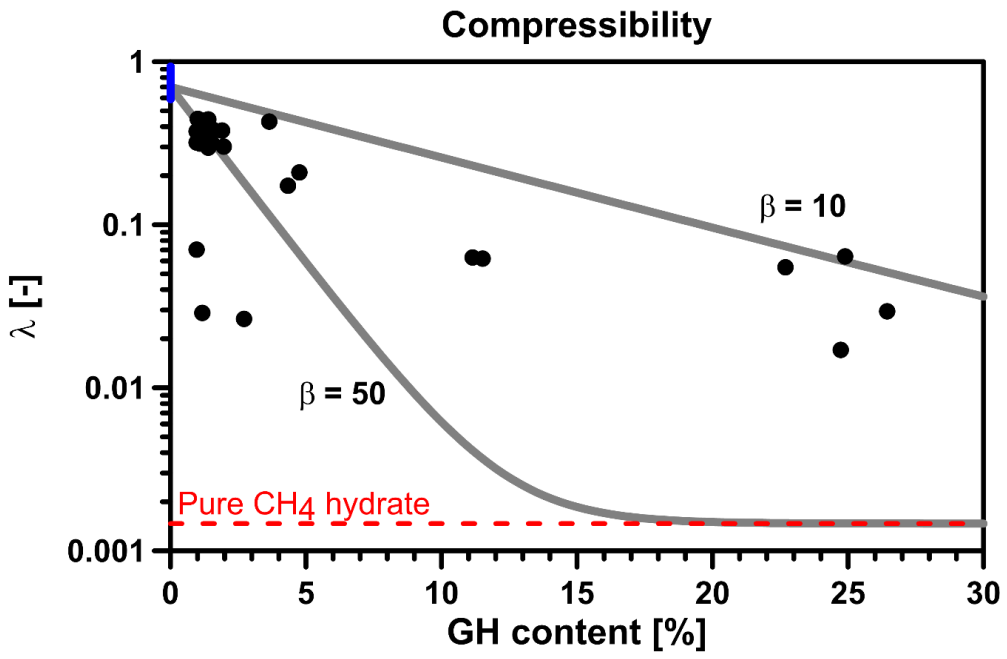
Mechanical properties: Strength (Su) and stiffness (G_{50}) against GH content

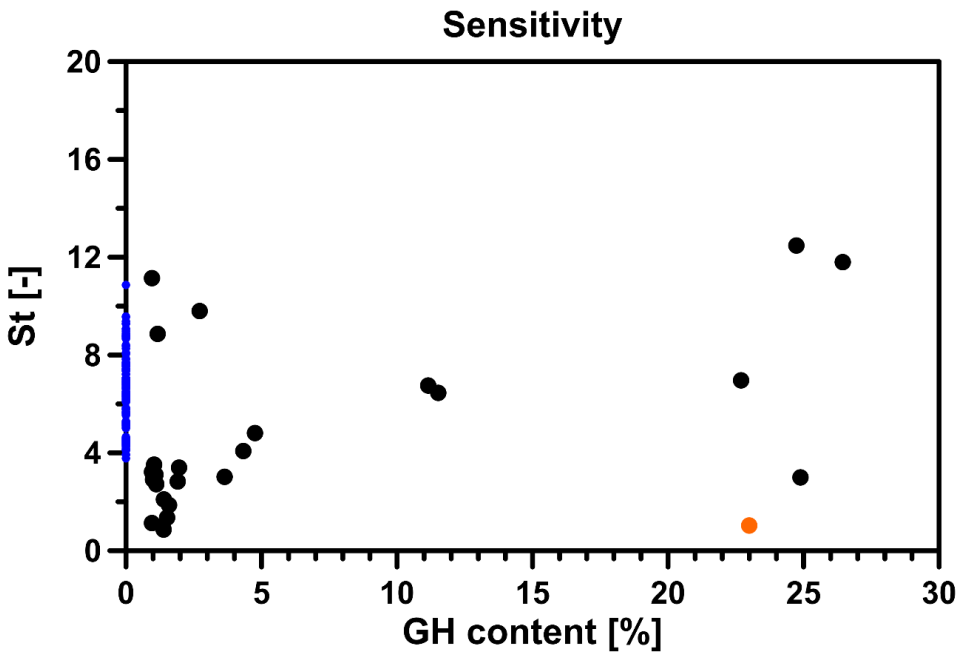




- Reference site from study area
- Gas hydrates-bearing site from study area
- Gas hydrates-bearing clayey silt (Yoneda et al., 2017)

Mechanical properties: Compressibility (λ) and sensitivity (St) against GH content





Sultan et al. (2010)

$$\lambda_h = \lambda_0 \left[1 - \left(1 - \left(\frac{\lambda_1}{\lambda_0}\right)\right)\left(1 - \exp\left(-\beta . \frac{S_h}{100}\right)\right)\right]$$

λ_0 = 0.7 – Purely water-saturated sediment

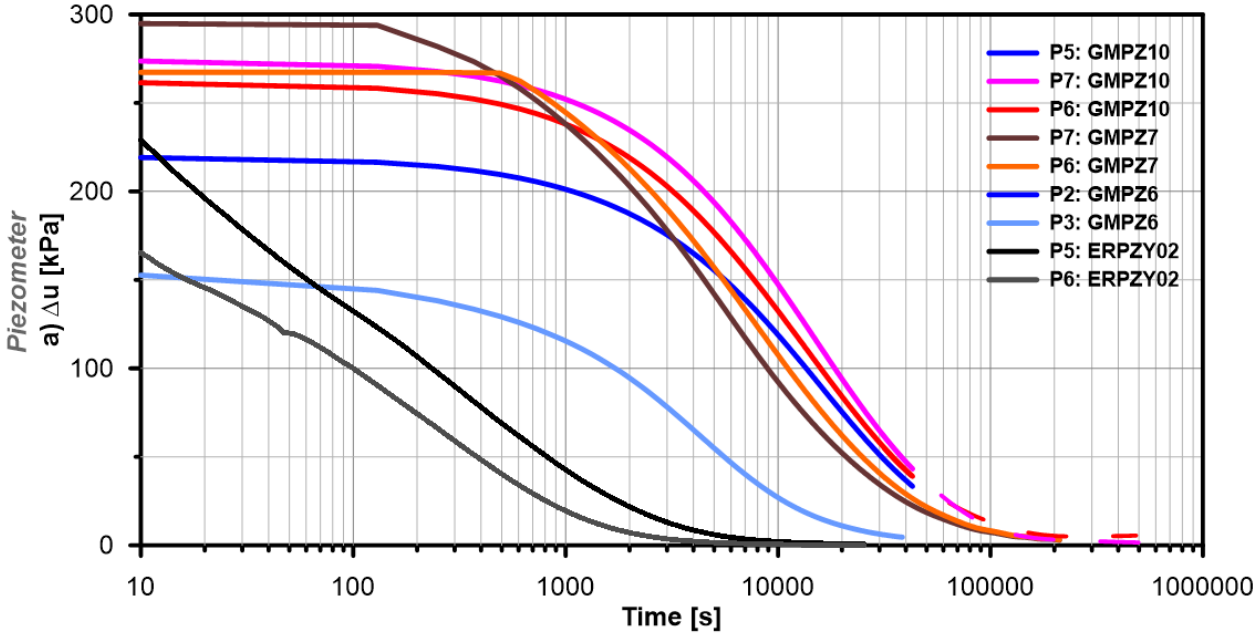
λ_1 = 0.00147 – Pure hydrate

β: *distribution and morphology*

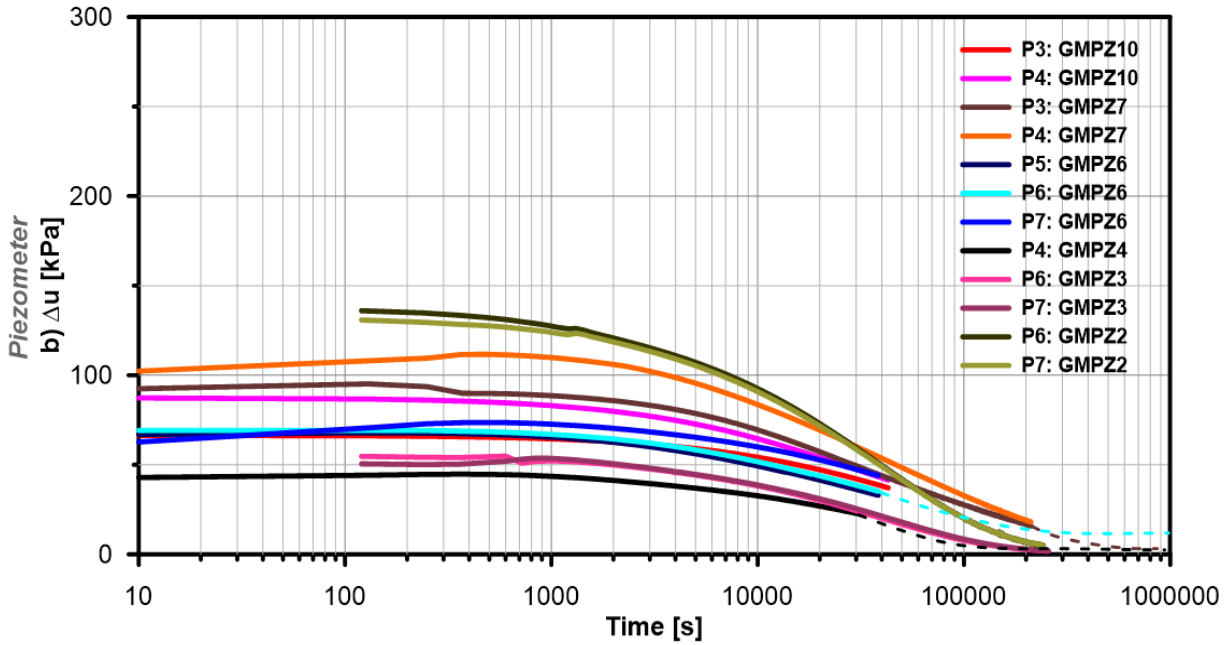
- Reference site from study area
- Gas hydrates-bearing site from study area
- Gas hydrates-bearing clayey silt (Yoneda et al., 2017)

Hydraulic properties: Dissipation curves

- Δu curves are observed to decrease in a monotonic way with time, which is indicative of a **contractive behaviour**.



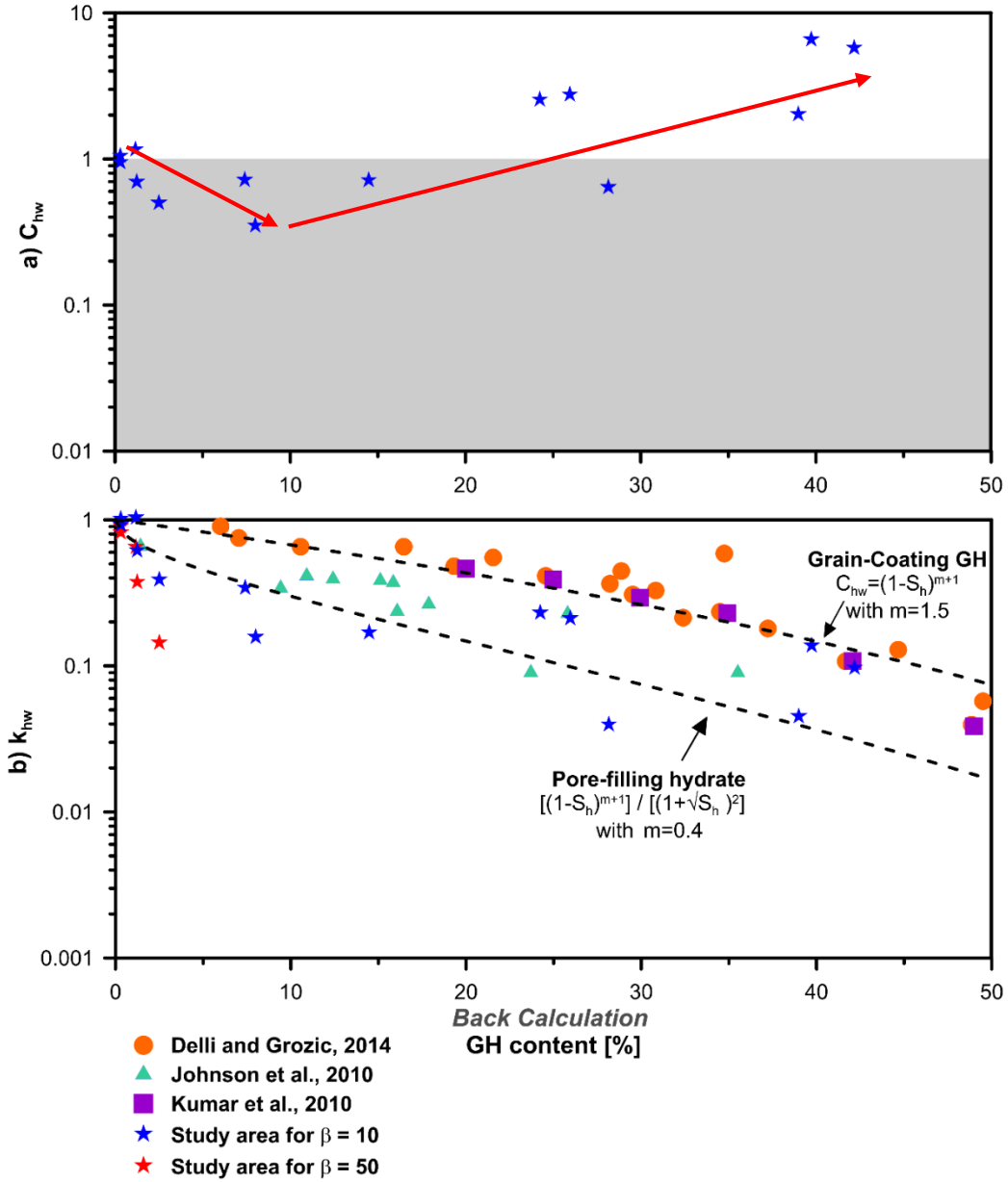
High initial excess pore-pressure pulse
$(\boldsymbol{U_{ini} > 150\ kPa})$



Low initial excess pore-pressure pulse
$(\boldsymbol{U_{ini} < 150 kPa})$

$$C_h = \frac{T^*.r^2\sqrt{I_r}}{t_{50}}$$

Hydraulic properties: Hydraulic diffusivity (C_{hw}), Relative permeability to water (k_{hw}) against GH content



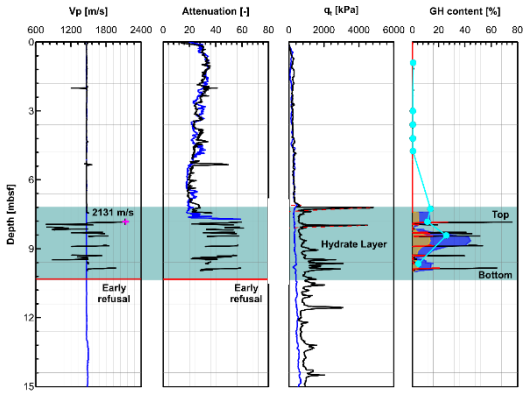
- For S_h values higher than 10%, C_{hw} values rising above 1 were linked to the:
  - Presence of fractures in the GH-sediment system,
  - Important decrease of compressibility,
  - Piezometer penetration.

$$k_{hw} = C_{hw}.\frac{\lambda_h}{\lambda_0}$$

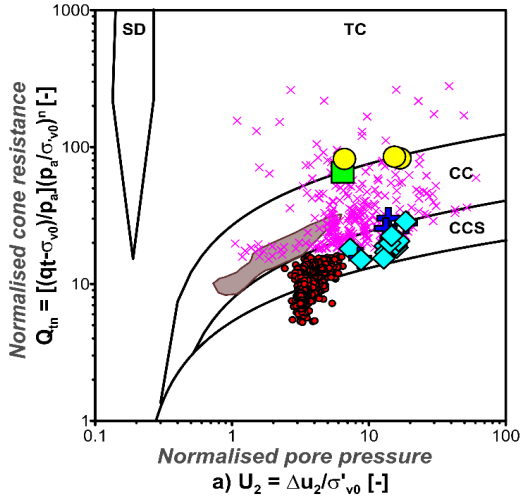
- The calculated k_{hw} data decrease with increasing S_h.

The general thought about the decrease of the hydraulic diffusivity with the increase of hydrate content cannot be applied systematically in natural sediment-hydrate systems.

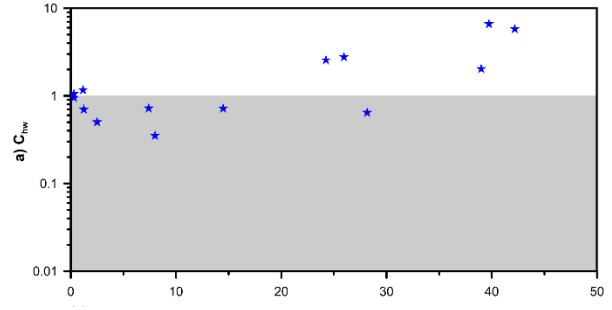
- **Detection and quantification:**
  - Positive Vp anomalies correlating with increase of geotechnical parameters are indicative of the presence of gas hydrate.
  - Using the effective medium theory and pore-water chloride analysis methods, gas hydrate content was estimated.



- **Mechanical properties:**
  - Gas hydrate-bearing clayey sediments are generally characterised by a contractive behaviour.
  - Soil behaviour classification charts might be a means to identify different gas hydrate morphologies.
  - The morphology/distribution of gas hydrate has a noticeable effect on the compressibility, stiffness and strength properties of their host clayey sediments.



- **Hydraulic Properties:**
  - Pore pressure dissipation data confirmed the contractive behaviour.
  - For S_h values higher than 10%, C_{hw} values rising above 1 were linked to the presence of fractures, important decrease of compressibility or piezometer penetration.



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Thank you for your attention

Taleb, F., Garziglia, S., & Sultan, N. (2018). *Hydro mechanical properties of gas hydrate bearing fine sediments from in situ testing*. Journal of Geophysical Research: Solid Earth, 123. https://doi.org/10.1029/2018JB015824