EGU General Assembly 2022

Direct Evidence of High Pore Pressure at the Toe of the Nankai Accretionary Prism.

Authors:

Pwavodi Joshua[1]

Mai-Linh Doan[1]

ISTerre, Université Grenoble Alpes, France

UGA Université Grenoble Alpes

ISTerre

PTDF Multi-Purpose Cooperative Society Limited

IODP International Ocean Discovery Program

This presentation participates in OSPP

EGU

Outstanding Student & PhD candidate Presentation contest

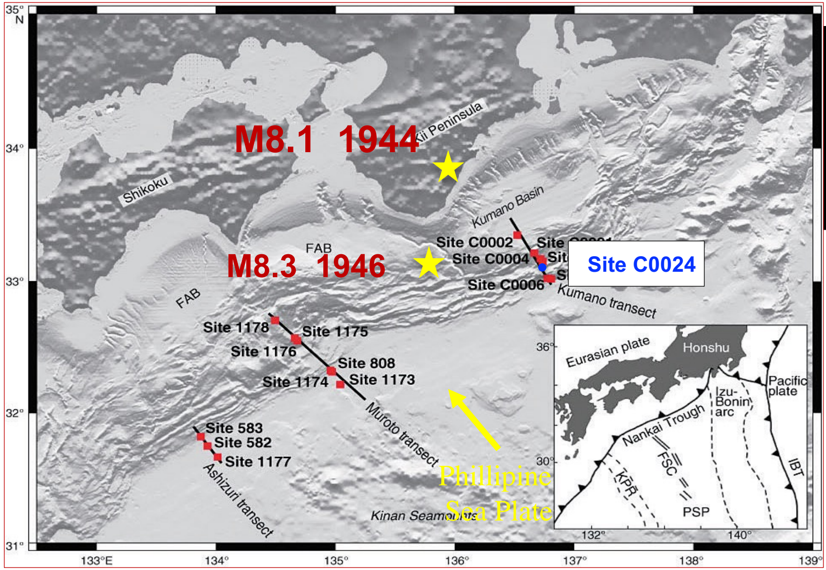
Subduction zones

Most devastating large magnitude earthquakes and tsunami occur in subduction zones.

Earthquakes and Fault Mechanics are affected:

- High Fluid flow
- Elevated pore fluid pressure
- Permeability

Nankai subduction zone



Moore et al., 2009

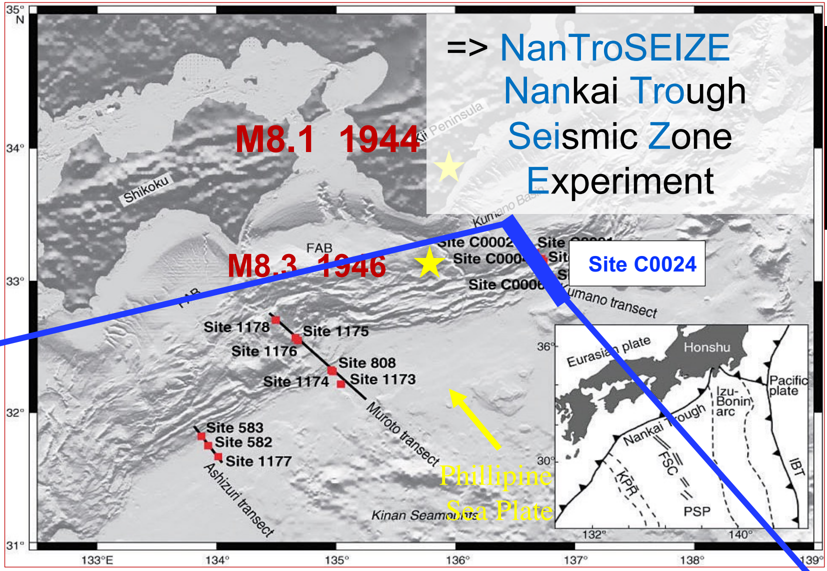
Subduction zones

Nankai subduction zone

Most devastating large magnitude earthquakes and tsunami occur in subduction zones.

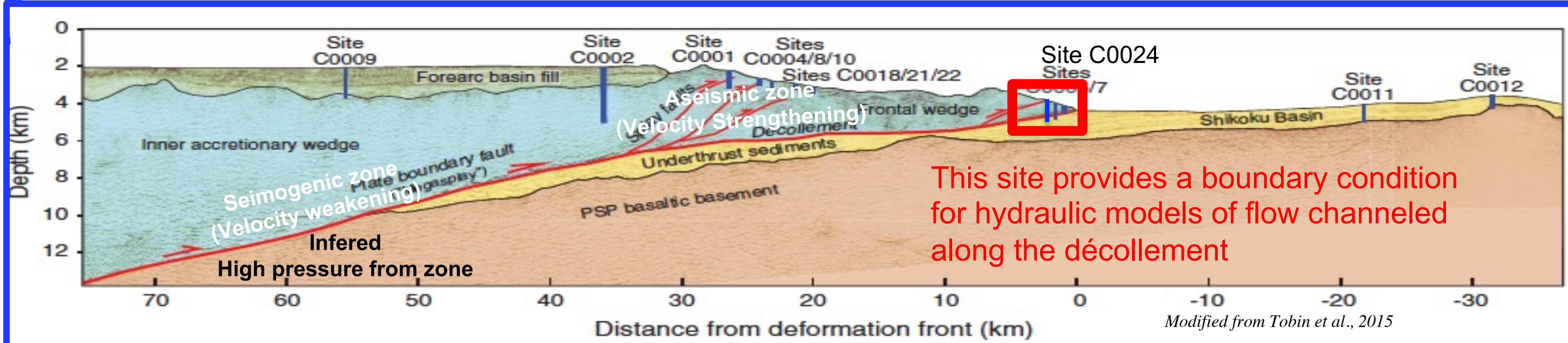
Earthquakes and Fault Mechanics are affected:

- High Fluid flow
- Elevated pore fluid pressure
- Permeability



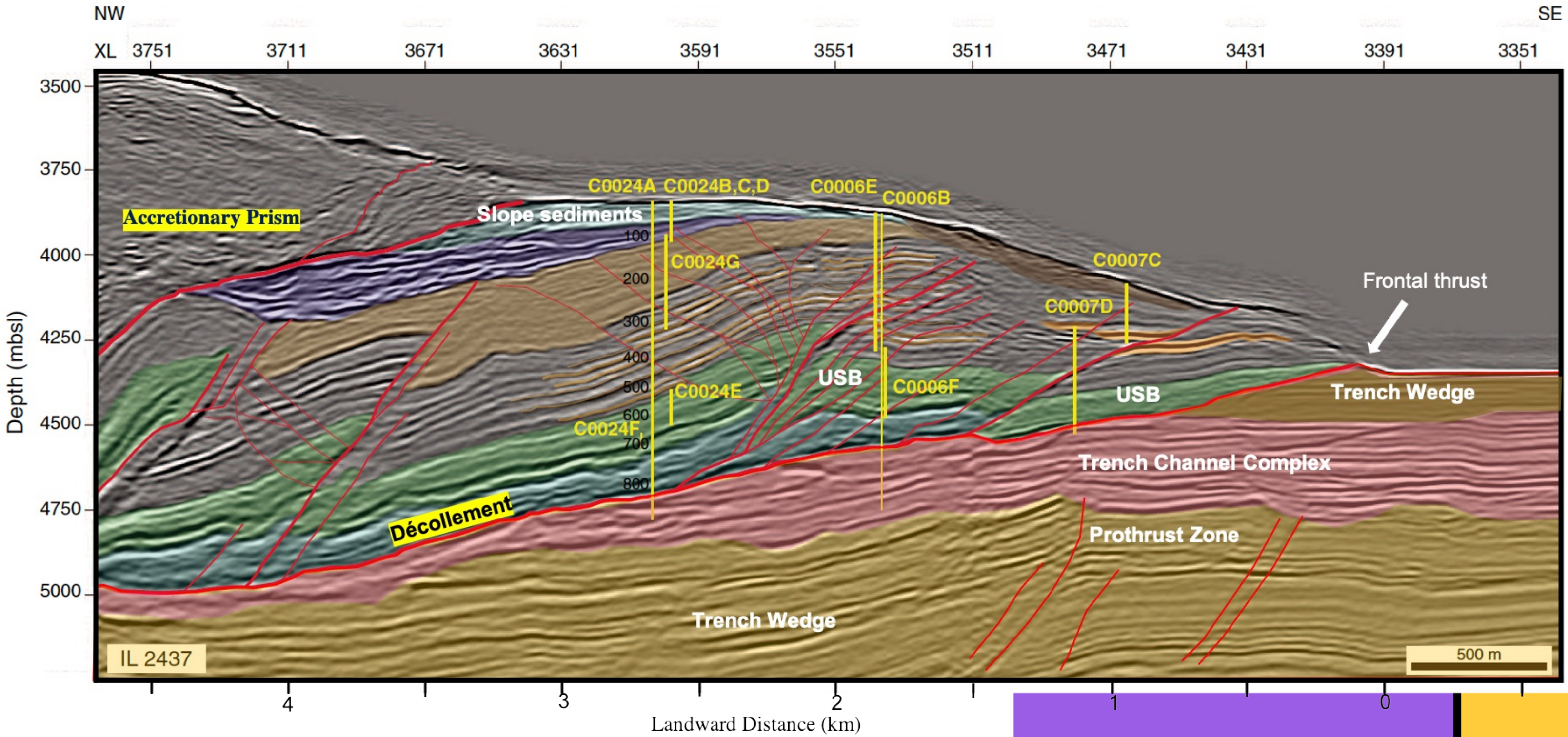
Moore et al., 2009

Site C0024



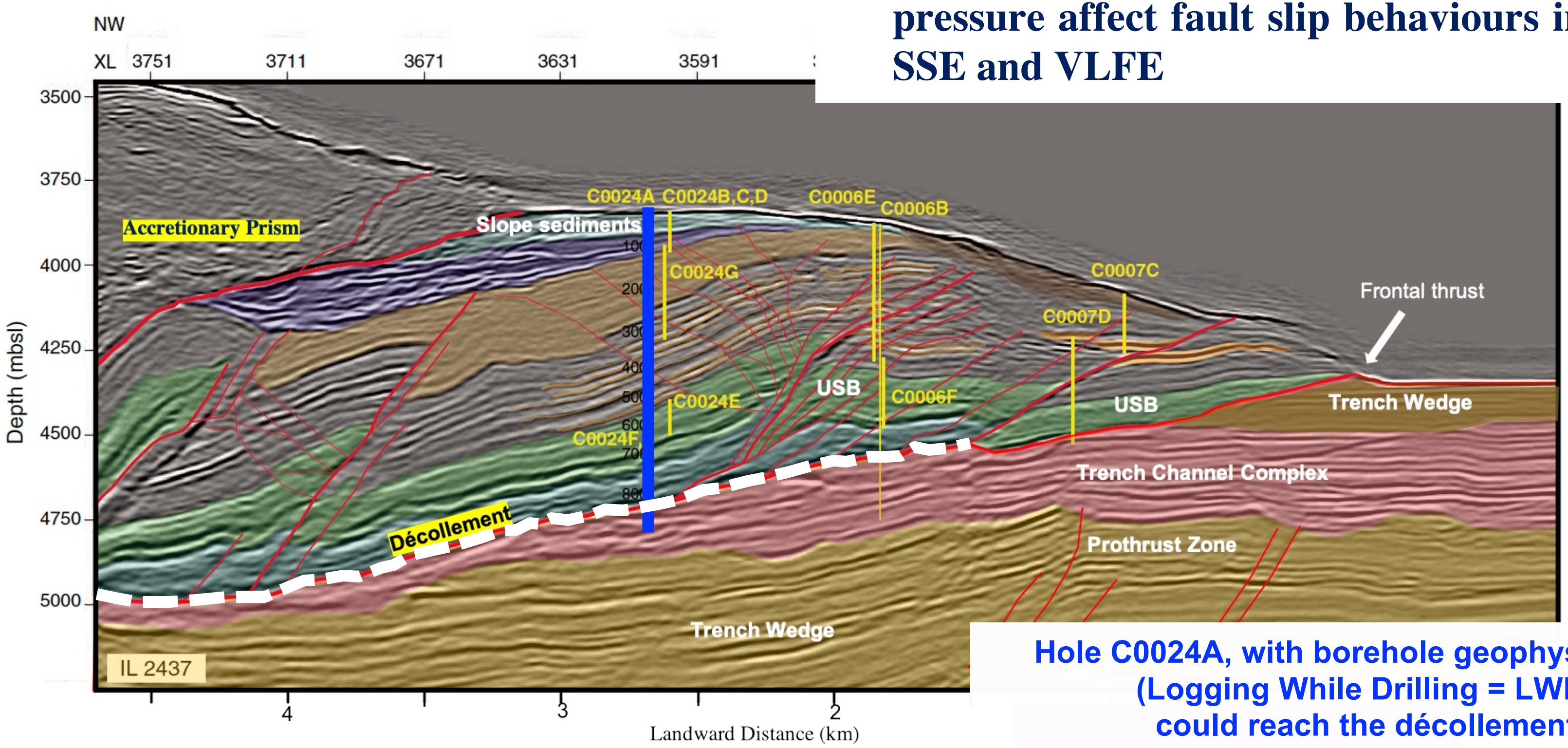
Modified from Tobin et al., 2015

Research Objectives



Research Objectives

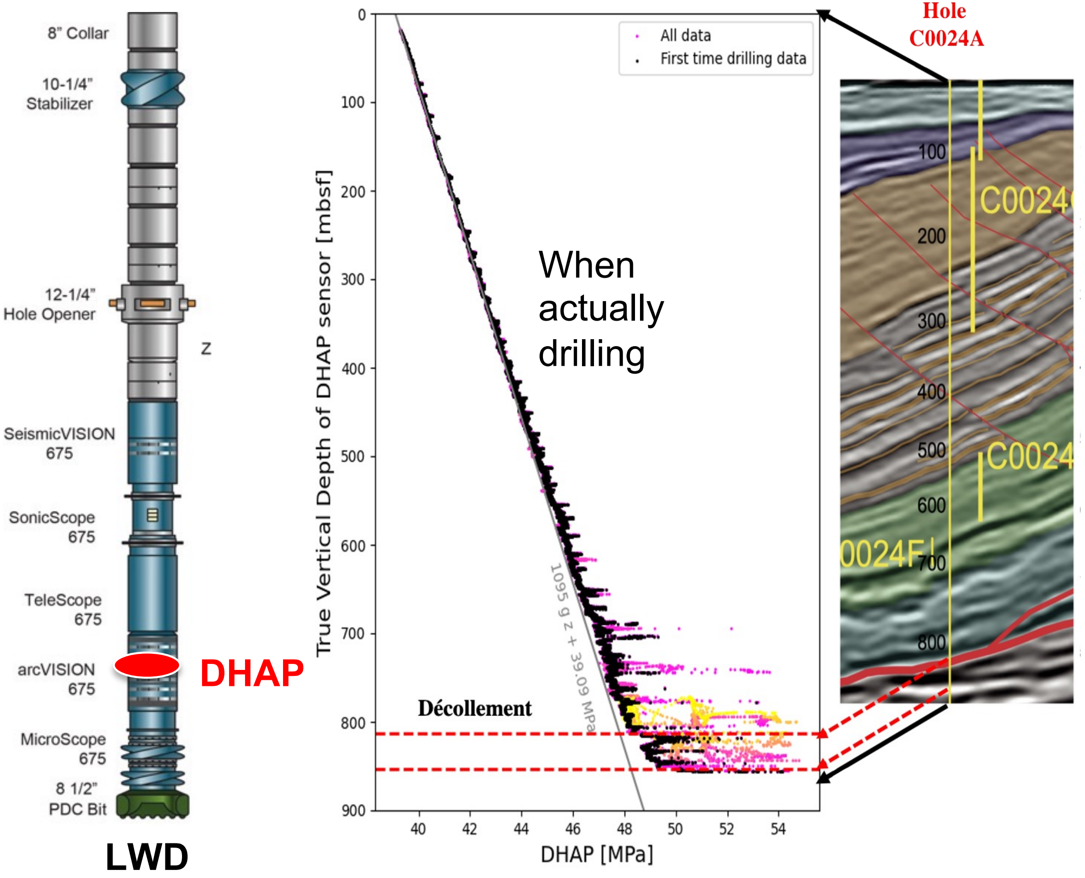
- To provide **continuous quantitative hydraulic** information of the Toe of the Nankai accretionary prism at **metric scale** with definite interpretation of the **fault zone**.
- Resolve how high fluid flow and elevated pore pressure affect fault slip behaviours including SSE and VLFE



Hole C0024A, with borehole geophysics only (Logging While Drilling = LWD) could reach the décollement

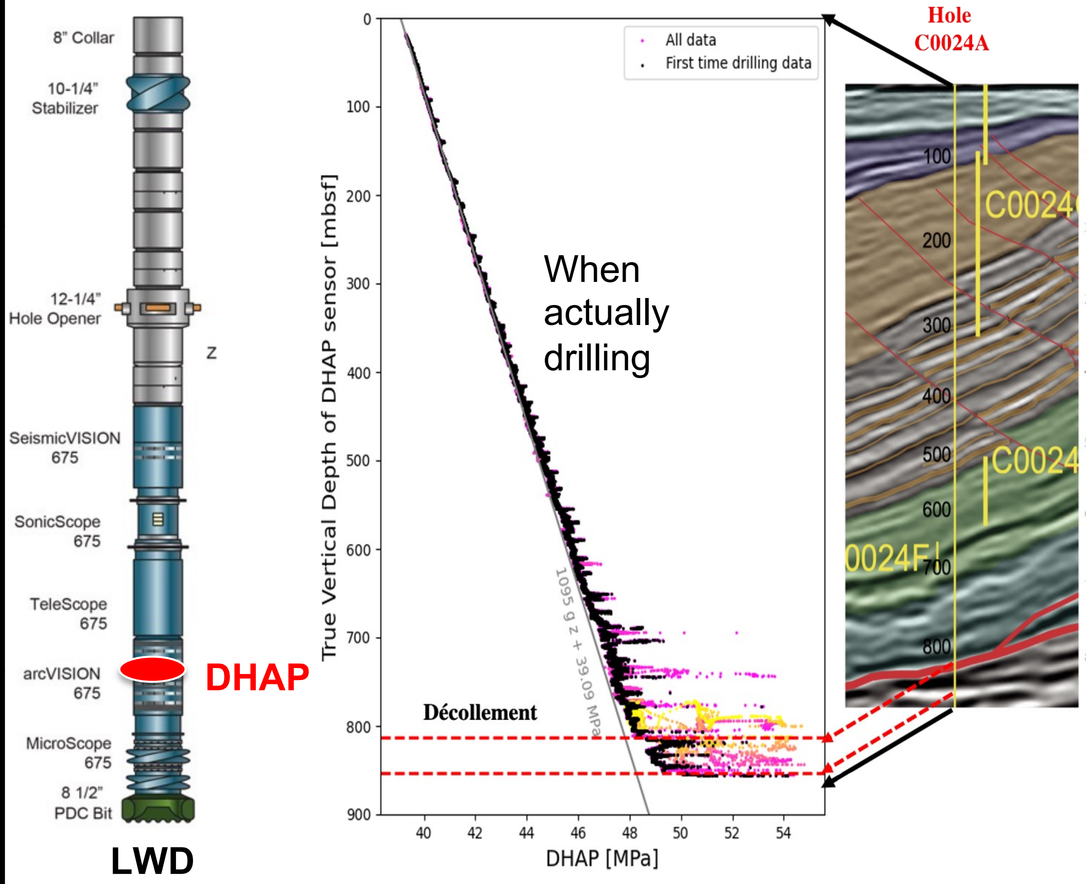
Methodology: DownHole Annular Pressure (DHAP)

DHAP sensor monitors Mud Pressure for drilling safety



Methodology: DownHole Annular Pressure (DHAP)

DHAP sensor monitors Mud Pressure for drilling safety



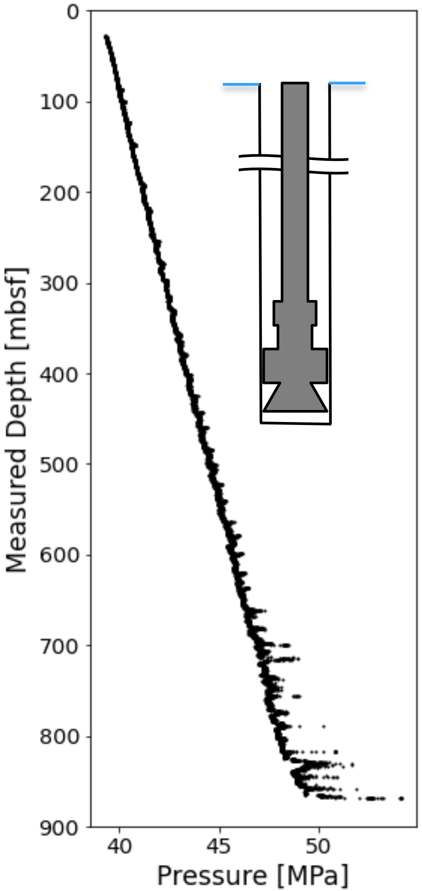
FLUID FLOW MODELING

- Forward Model
- Inversion Model

Influx / Outflux

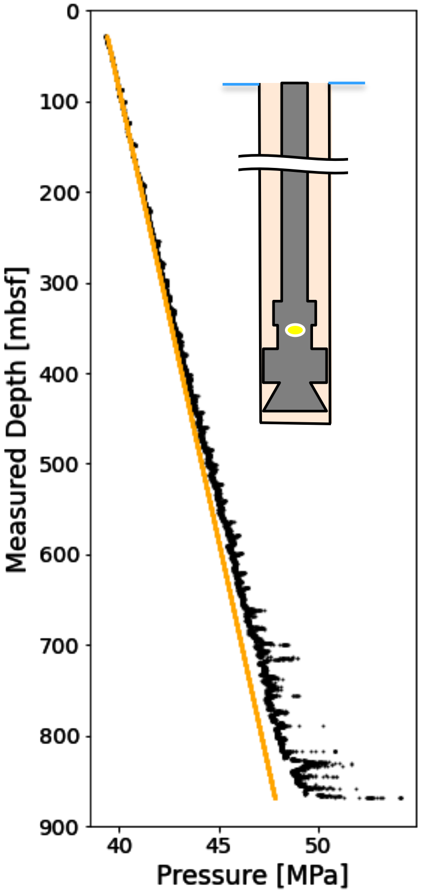
Determine flow contribution **In** or **Out** of the Borehole

Results : Inflow from modeling of Mud Pressure (DHAP)



Hydraulic Model of Mud Pressure

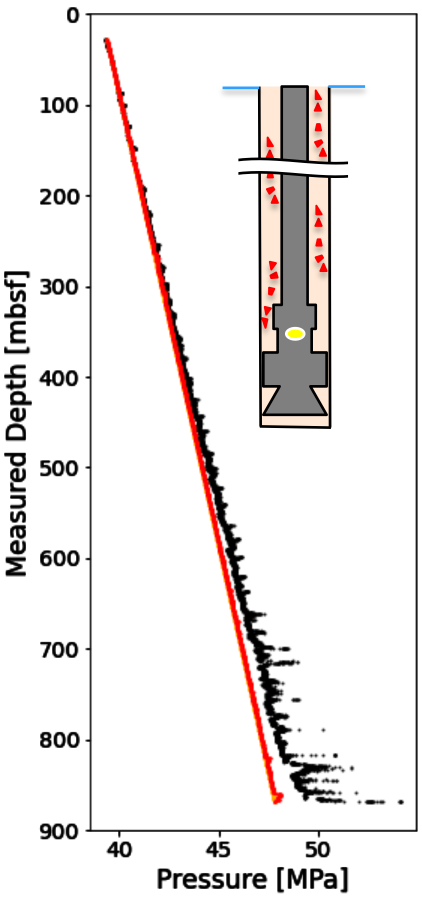
Results : Inflow from modeling of Mud Pressure (DHAP)



Hydraulic Model of Mud Pressure

Hydrostatic clean mud density

Results : Inflow from modeling of Mud Pressure (DHAP)

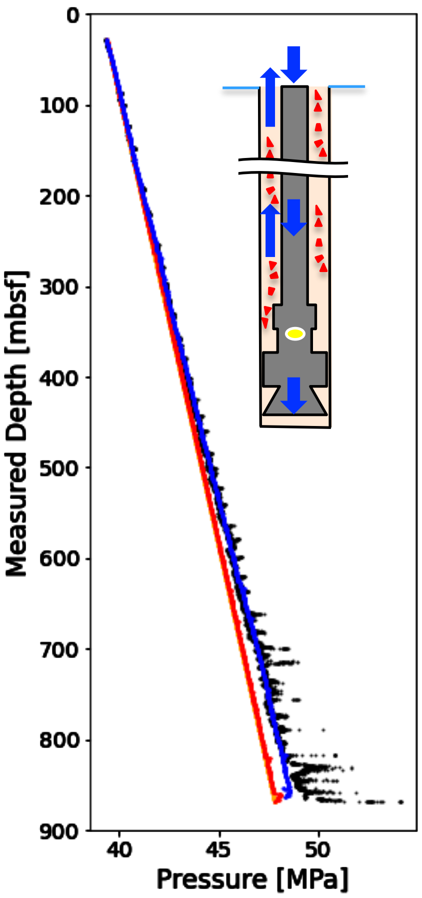


Hydraulic Model of Mud Pressure

Hydrostatic clean mud density

+ Weight of cuttings

Results : Inflow from modeling of Mud Pressure (DHAP)



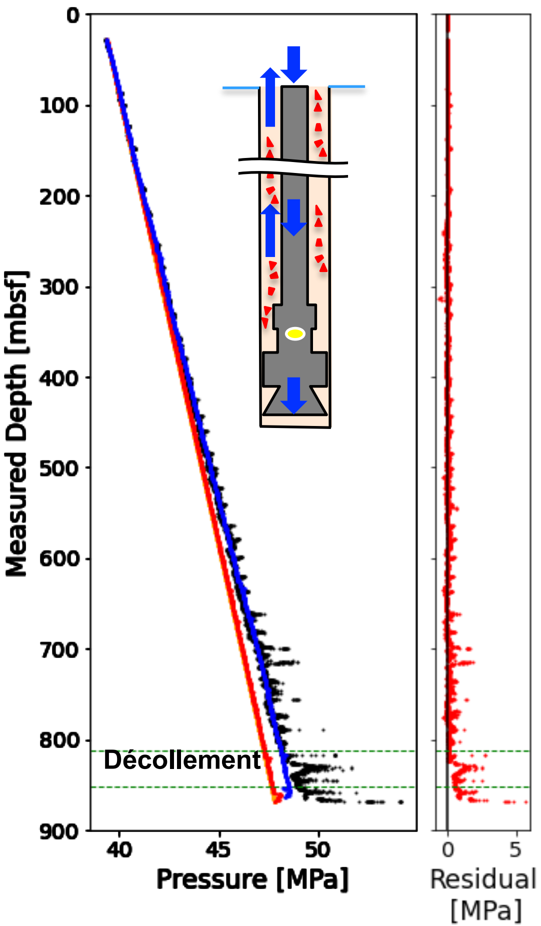
Hydraulic Model of Mud Pressure

Hydrostatic clean mud density

+ Weight of cuttings

+ Hydraulic (dynamic) losses due to mud circulation along the borehole

Results : Inflow from modeling of Mud Pressure (DHAP)



Hydraulic Model of Mud Pressure

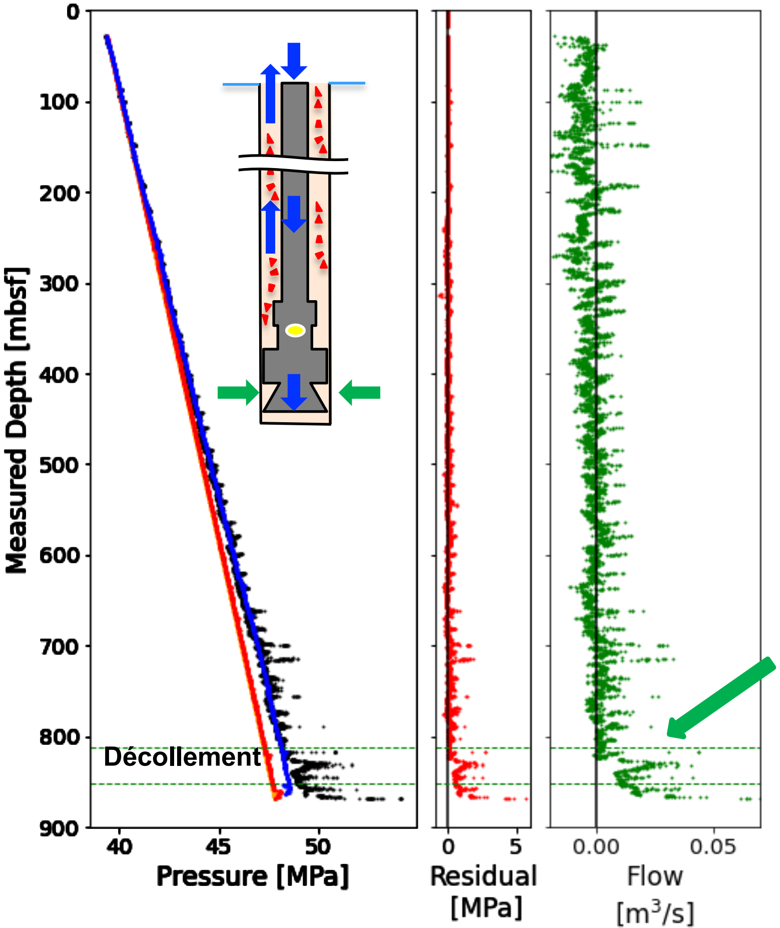
Hydrostatic clean mud density

+ Weight of cuttings

+ Hydraulic (dynamic) losses due to mud circulation along the borehole

Mud pressure anomaly not explained by the hydraulic model

Results : Inflow from modeling of Mud Pressure (DHAP)



Hydraulic Model of Mud Pressure

Hydrostatic clean mud density

+ Weight of cuttings

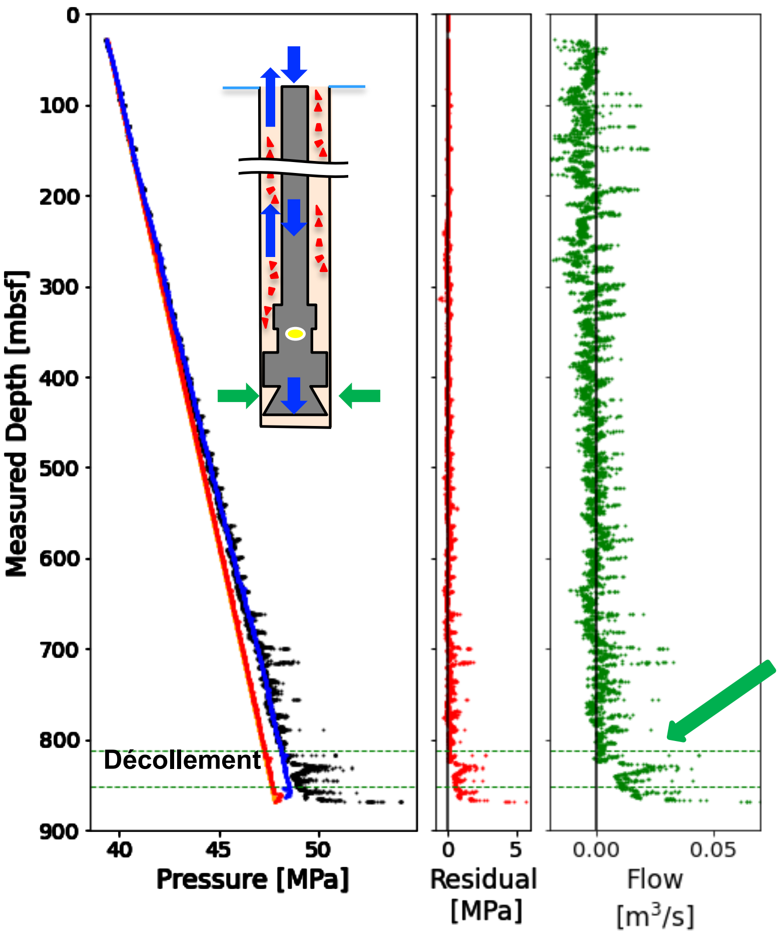
+ Hydraulic (dynamic) losses due to mud circulation along the borehole

Mud pressure anomaly not explained by the hydraulic model

⇨

large inflow into the borehole when crossing the décollement

Results : Inflow from modeling of Mud Pressure (DHAP)



Hydraulic Model of Mud Pressure

Hydrostatic clean mud density
+ Weight of cuttings
+ Hydraulic (dynamic) losses due to mud circulation along the borehole

Mud pressure anomaly not explained by the hydraulic model

⇨

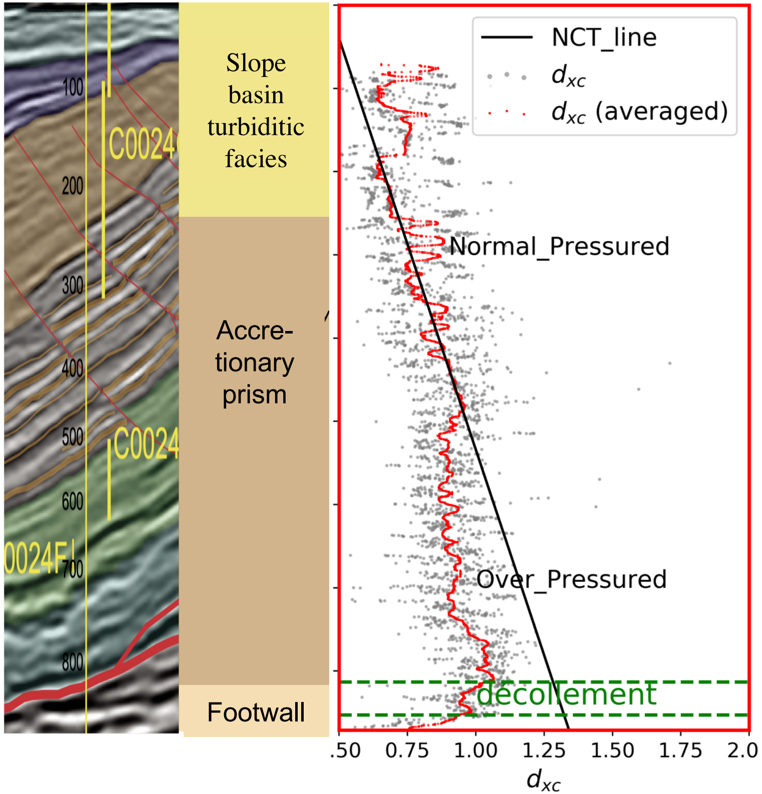
large inflow into the borehole when crossing the décollement

Flow = Permeability × Pressure gradient

Results: Inferring Pore Pressure from Eaton's Model

d_{xc} – exponent method

Proxy for "un-drillability", if lithology is the same, but *d*-exponent coefficient decreases.



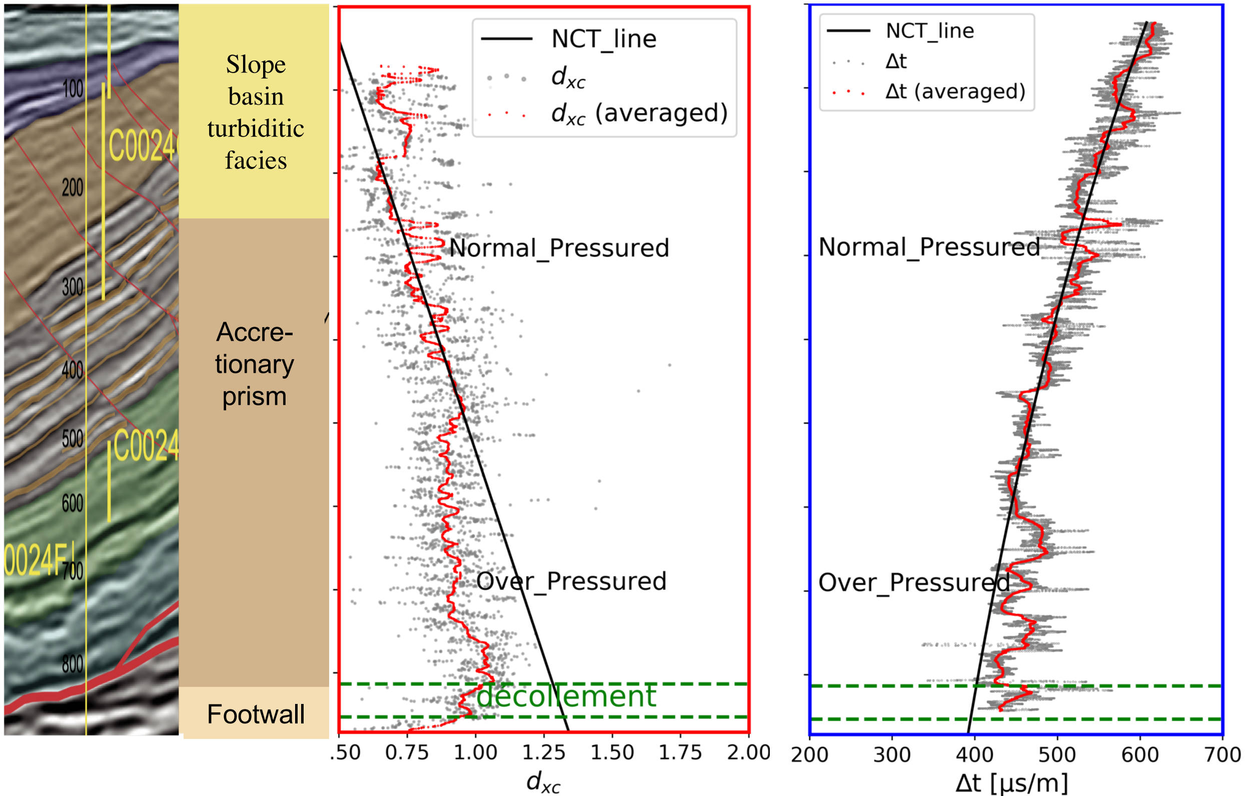
Results: Inferring Pore Pressure from Eaton's Model

d_{xc} – exponent method

Proxy for "un-drillability", if lithology is the same, but *d*-exponent coefficient decreases.

Δt –sonic method

Seismic slowness follows an exponential decay with depth.



Results: Inferring Pore Pressure from Eaton's Model

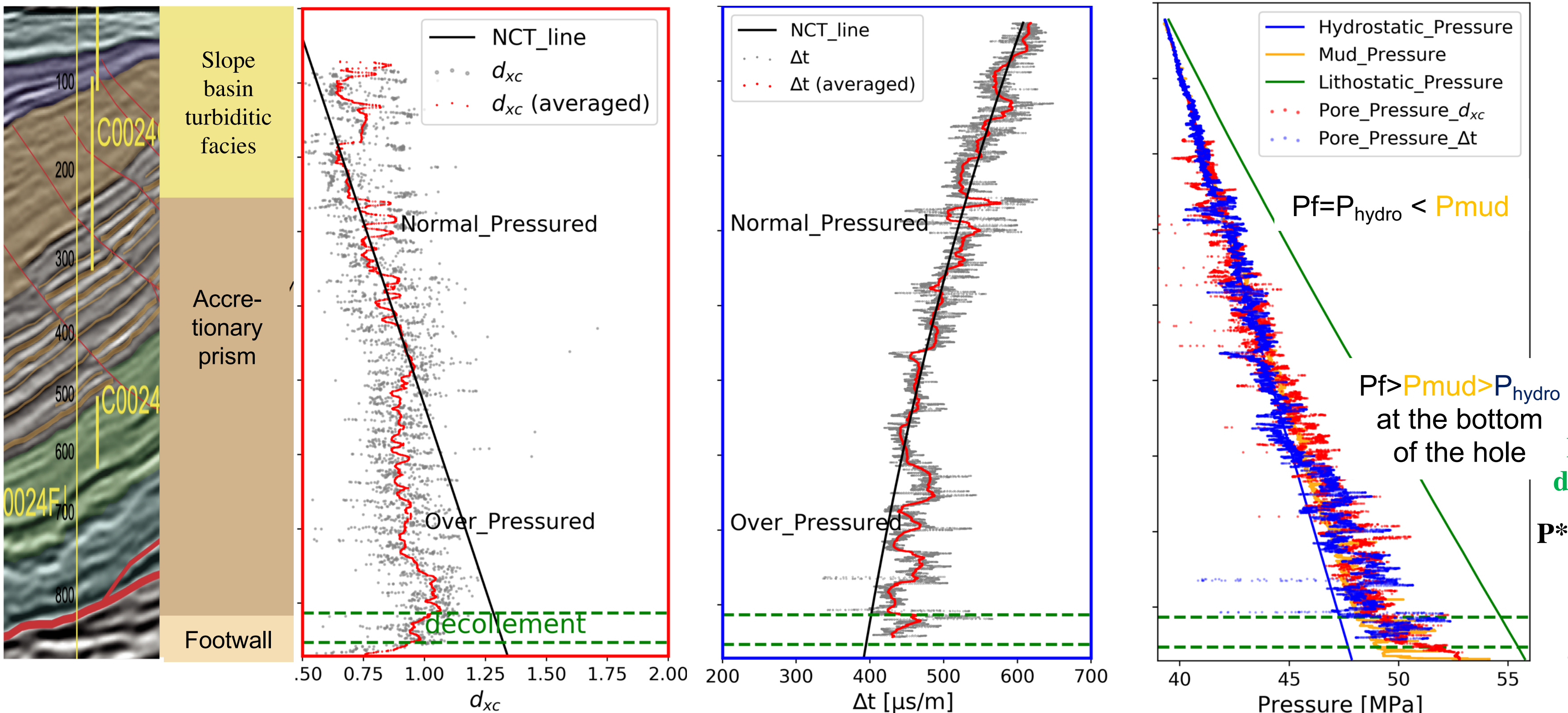
d_{xc} – exponent method

Proxy for "un-drillability", if lithology is the same, but *d*-exponent coefficient decreases.

Δt – sonic method

Seismic slowness follows an exponential decay with depth.

Combined Pore pressure (d_{xc} & Δt) Result

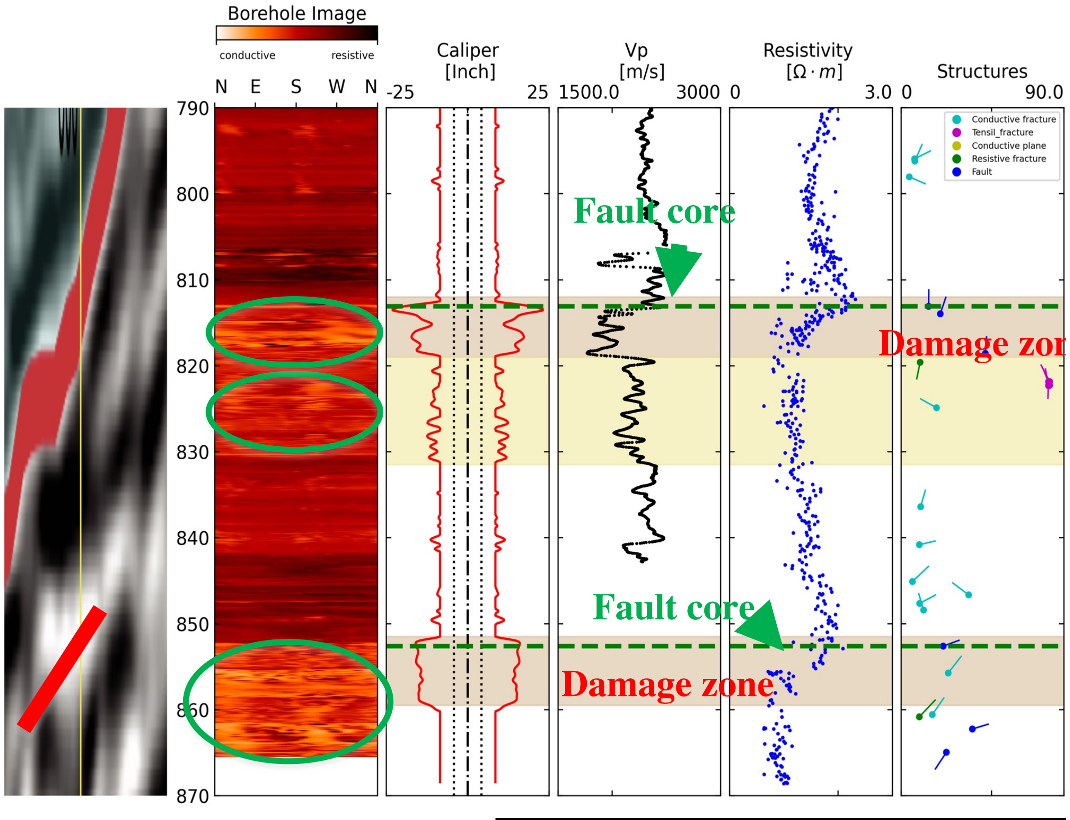


Below the décollement

$P^* = 4.79$MPa

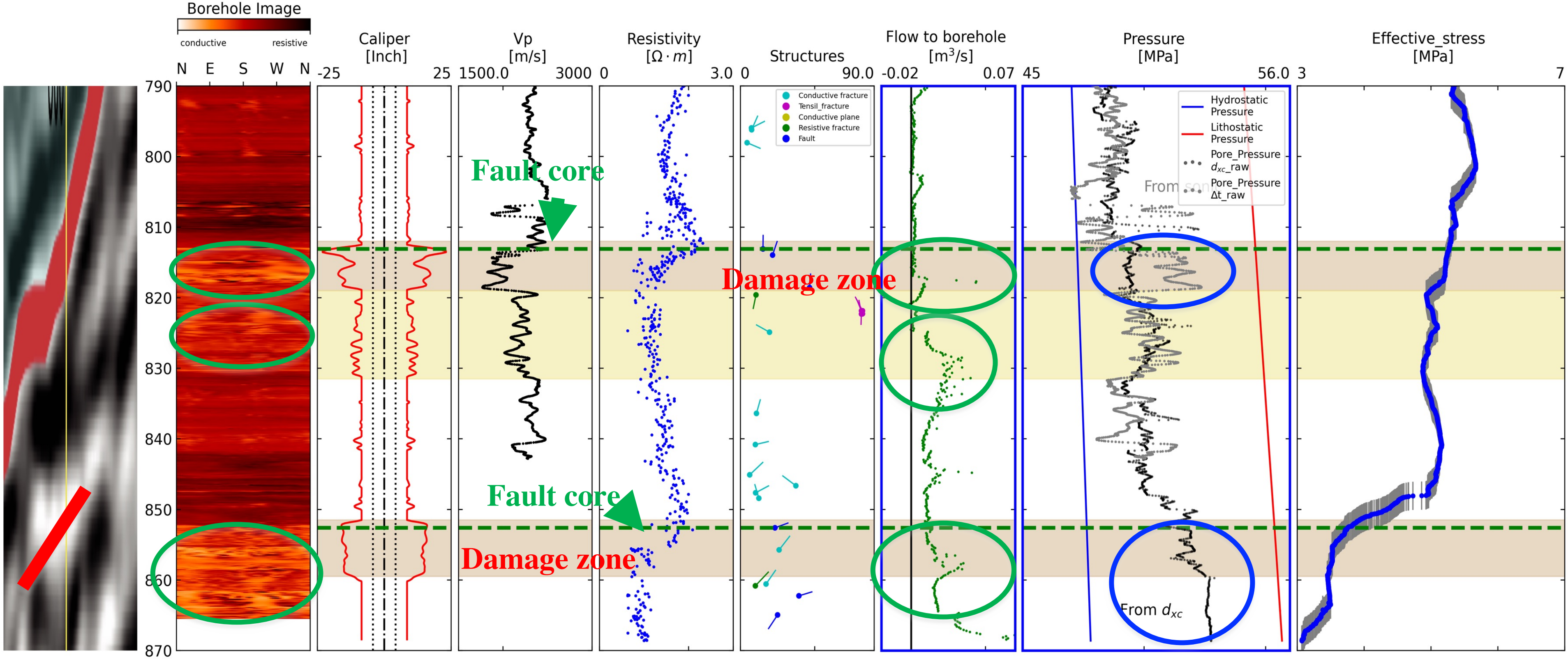
$\lambda^* = 62\%$ of the overburden stress

Discussion: Hydraulic structure of the décollement

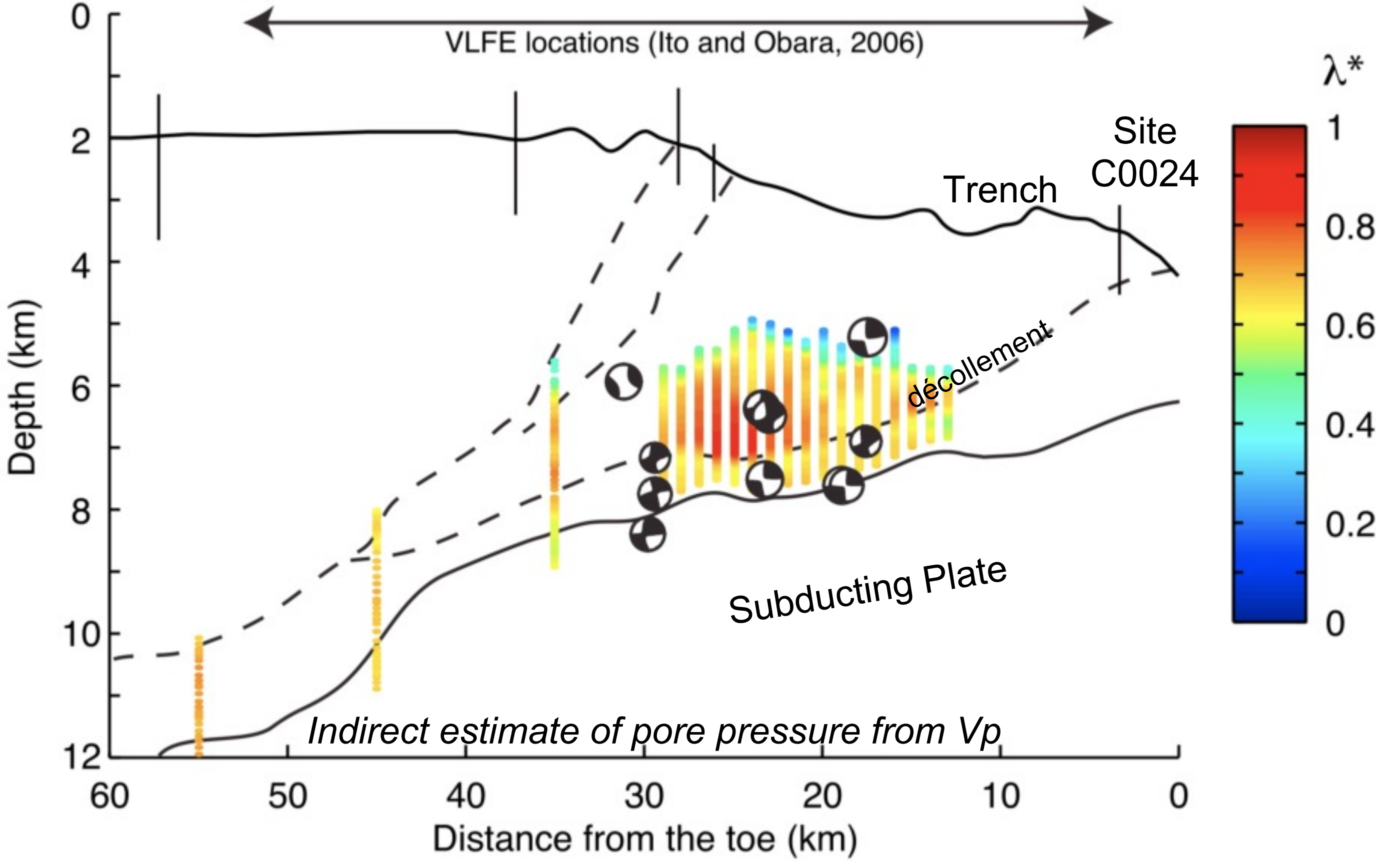


Discussion: Hydraulic structure of the décollement

- ❖ **No hydraulic connection between the hanging wall and the footwall**
- ❖ **The footwall is the locus of fluid flow from the formation with higher pore pressure.**
- ❖ **The fluid flow within the damage zone is chanellised.**



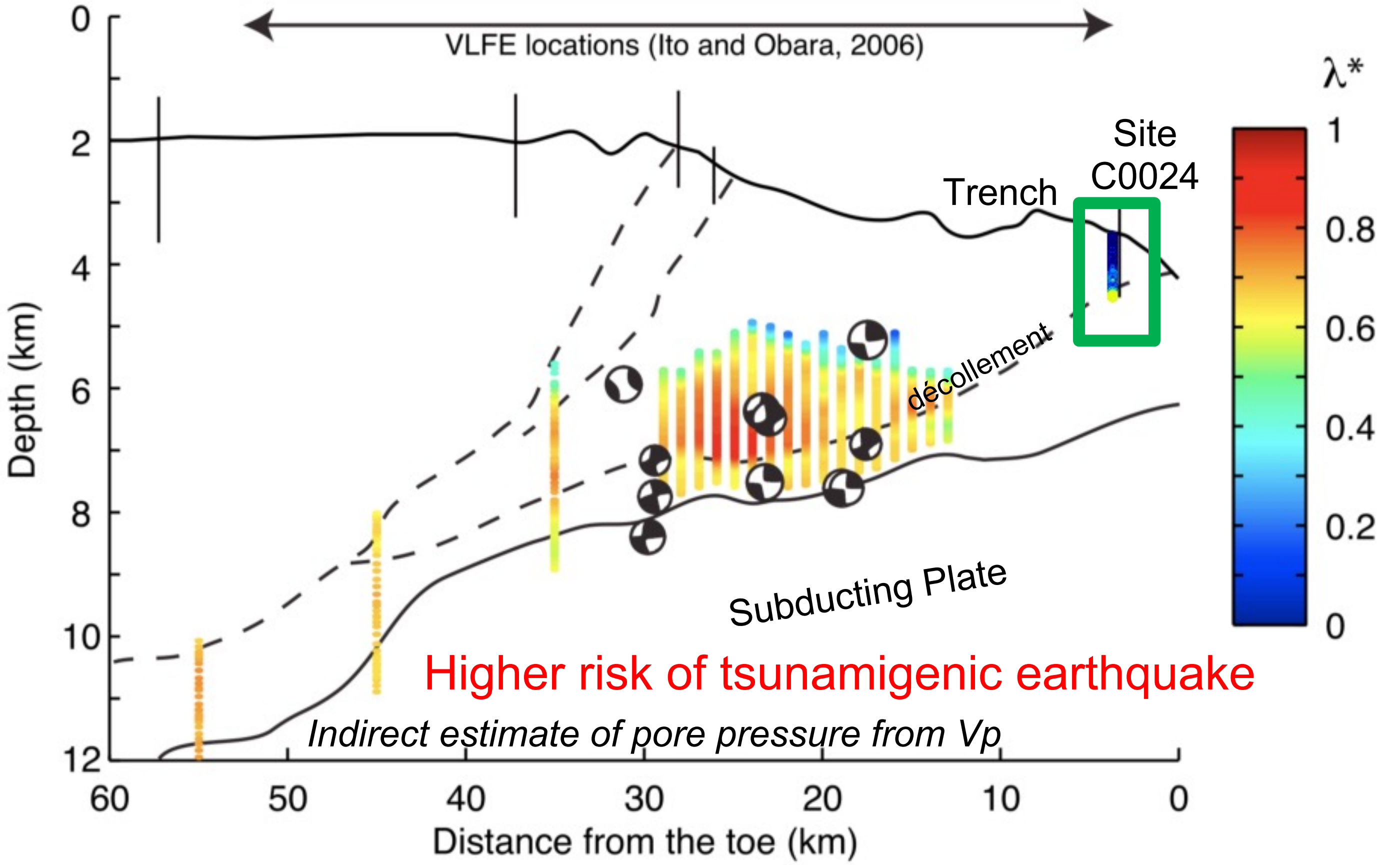
Implication for seismotectonics



$$\lambda^* = \frac{P_f - P_{hyd}}{\sigma_v - P_{hyd}}$$

Kitajima et al, 2012

Implication for seismotectonics

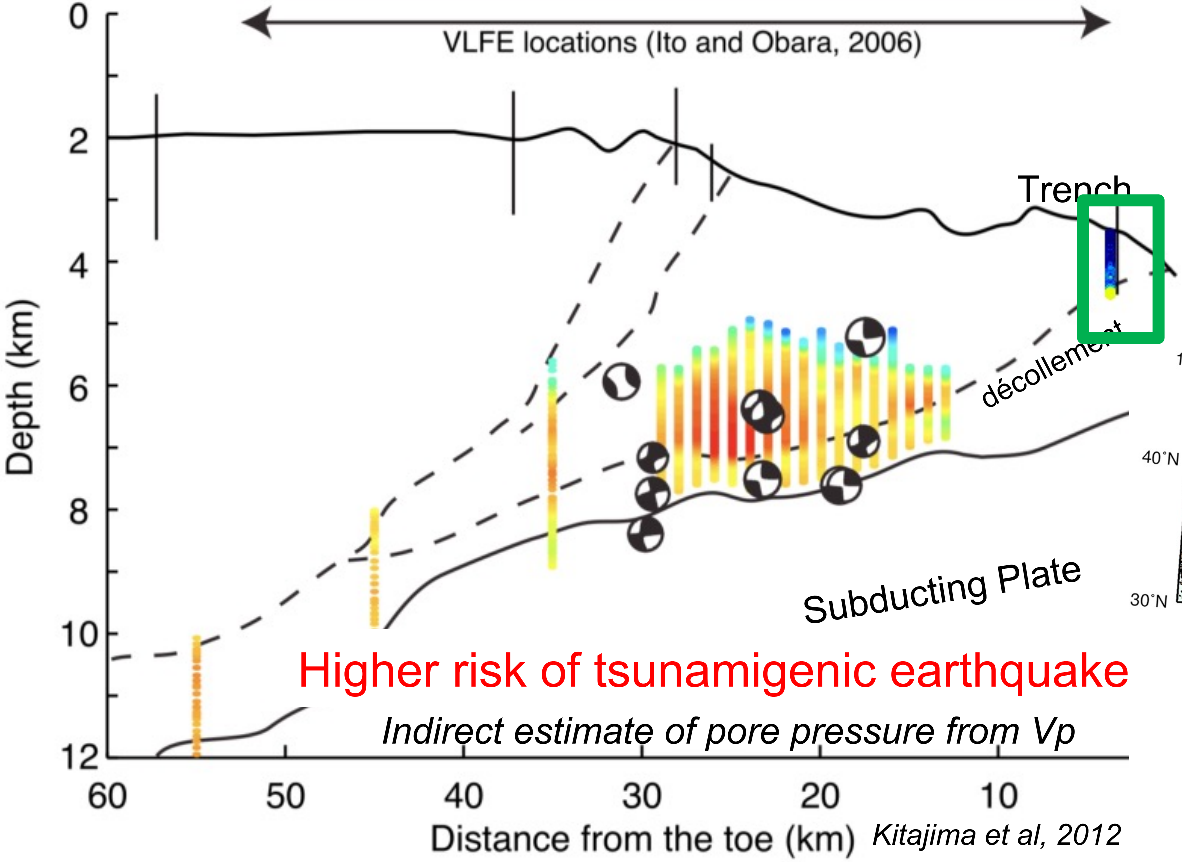


$$\lambda^* = \frac{P_f - P_{hyd}}{\sigma_v - P_{hyd}}$$

Extension of the high pressure zone to the toe

Kitajima et al, 2012

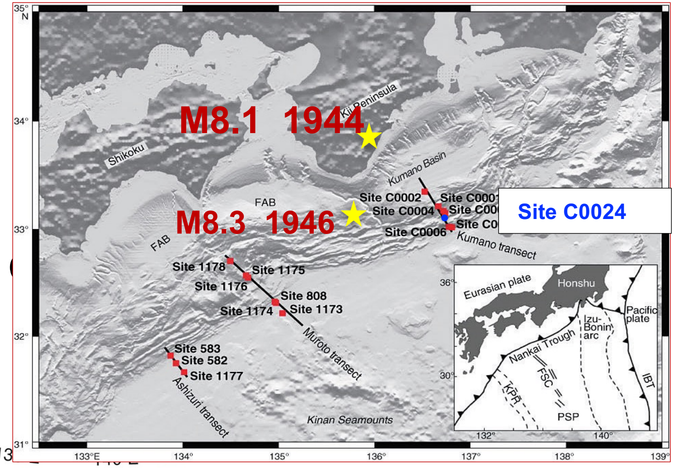
Implication for seismotectonics



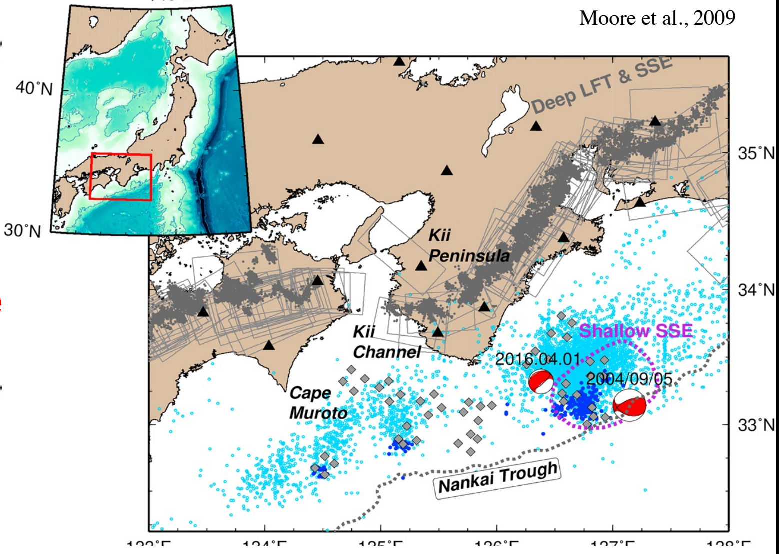
Higher risk of tsunamigenic earthquake

Indirect estimate of pore pressure from Vp

Kitajima et al, 2012



Moore et al., 2009



Takemura et al 20

Conclusions

- We developed a methodology to characterize the hydraulic state along the C0024A borehole, by processing both drilling and geophysical data, in both time and space.
- Pore pressure increase is pervasive at deeper depths within the accretionary prism and not only at the fault zone.
- The décollement fault zone is associated to an hydraulic anomaly with large fluid flow (>$0.05 m^3/s$) and high pore pressure ($P^* = 0/04 - 4.79$MPa and $\lambda^* = 62\%$)
- High pressure propagates up to the toe of the accretionary prism, favouring SSE and tsunamigenic earthquakes.

Contact:

Joshua.pwavodi@univ-grenoble-alpes.fr

*Open for postdocs at the end 2022

Abstract: