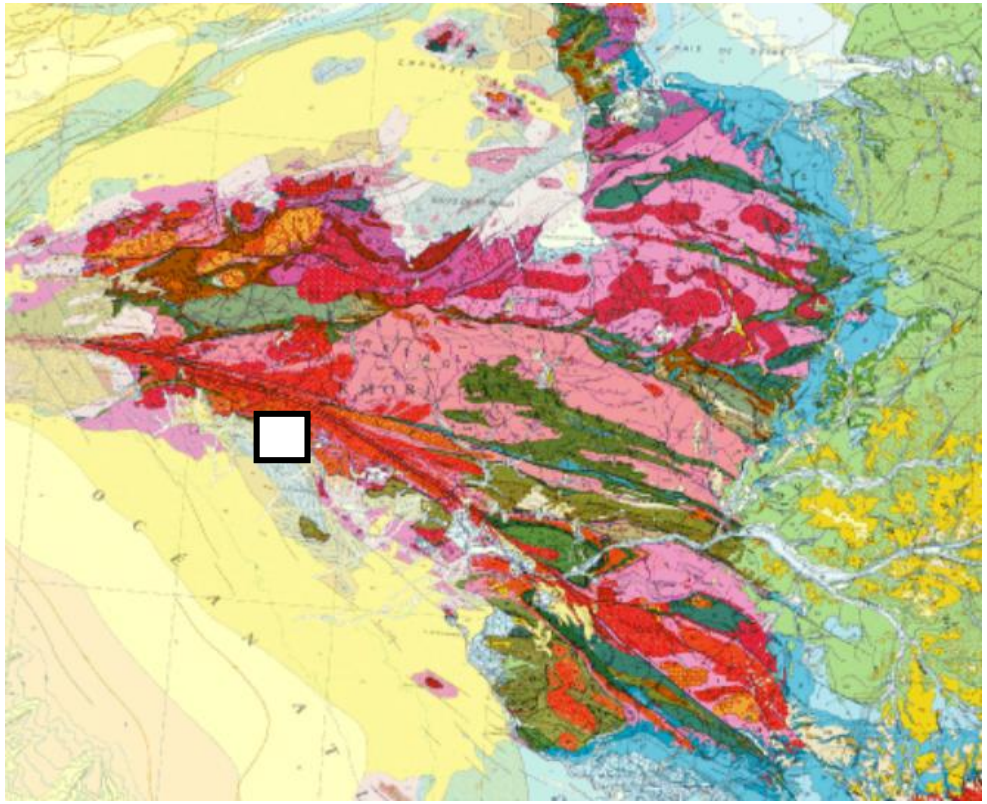
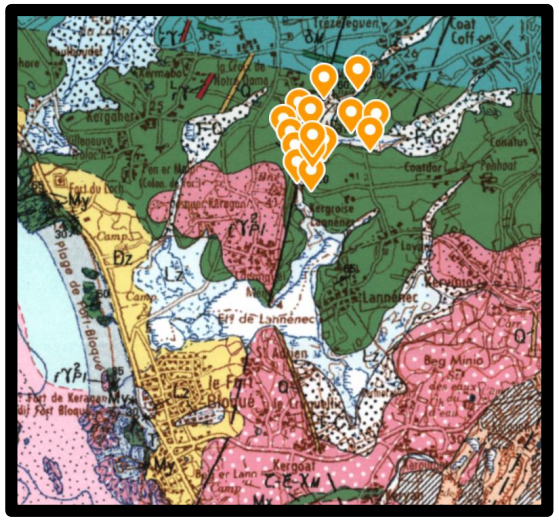
Transport and **reactivity** of **Dissolved Oxygen** in a fractured aquifer



Guidel study-site



Camille Bouchez, Thierry Labasque, Ivan Osorio, Nicolas Lavenant, Julien Farasin, Aurélie Guillou, Laurent Longuevergne, Olivier Bour and Tanguy Le Borgne

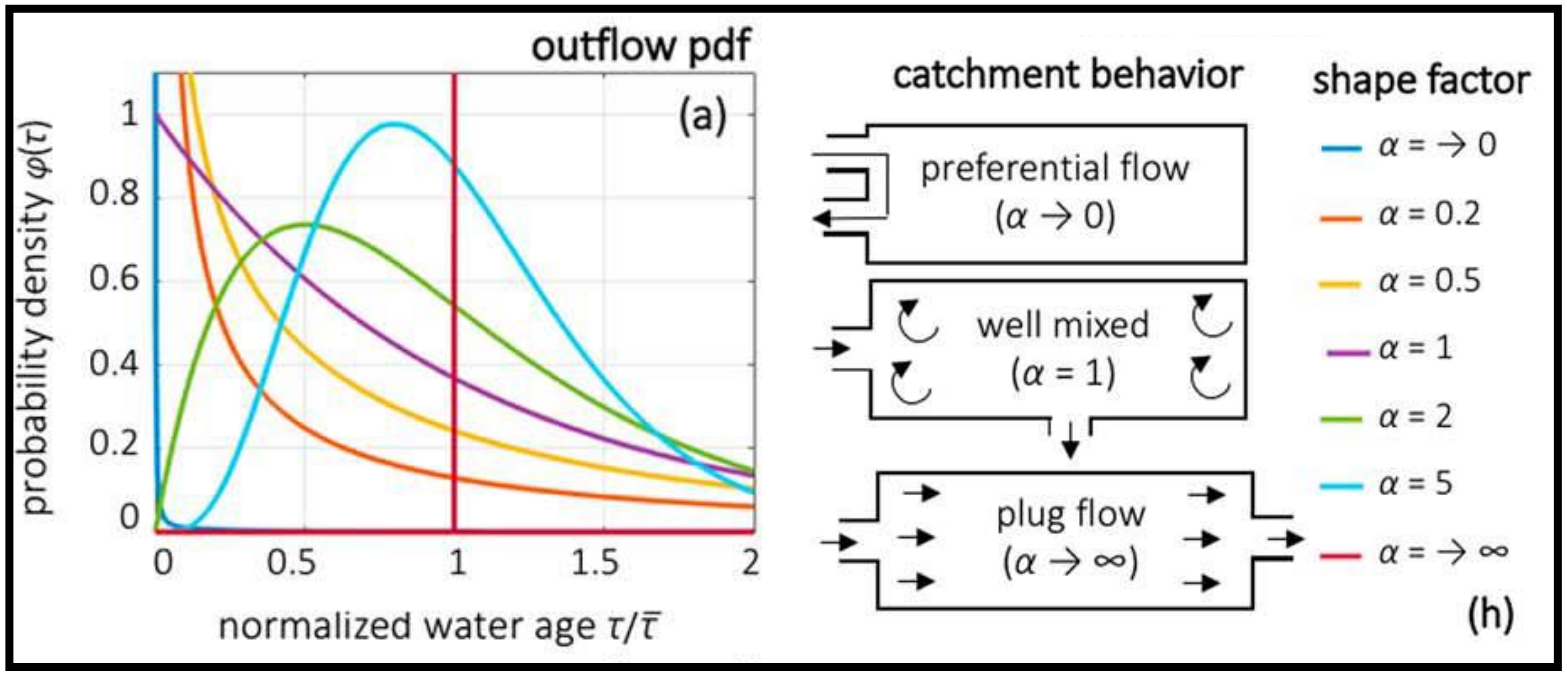
Geosciences Rennes, France

Groundwater Quality Conference - 2019

How can Transport and Reactivity be conceptualised in an aquifer?

Flow structure in an aquifer :

- Hydraulic response time
- Catchment transit time distributions
- Storage residence time distributions



Berghuijs et al., GRL, 2017

Biological reactions

Rock weathering

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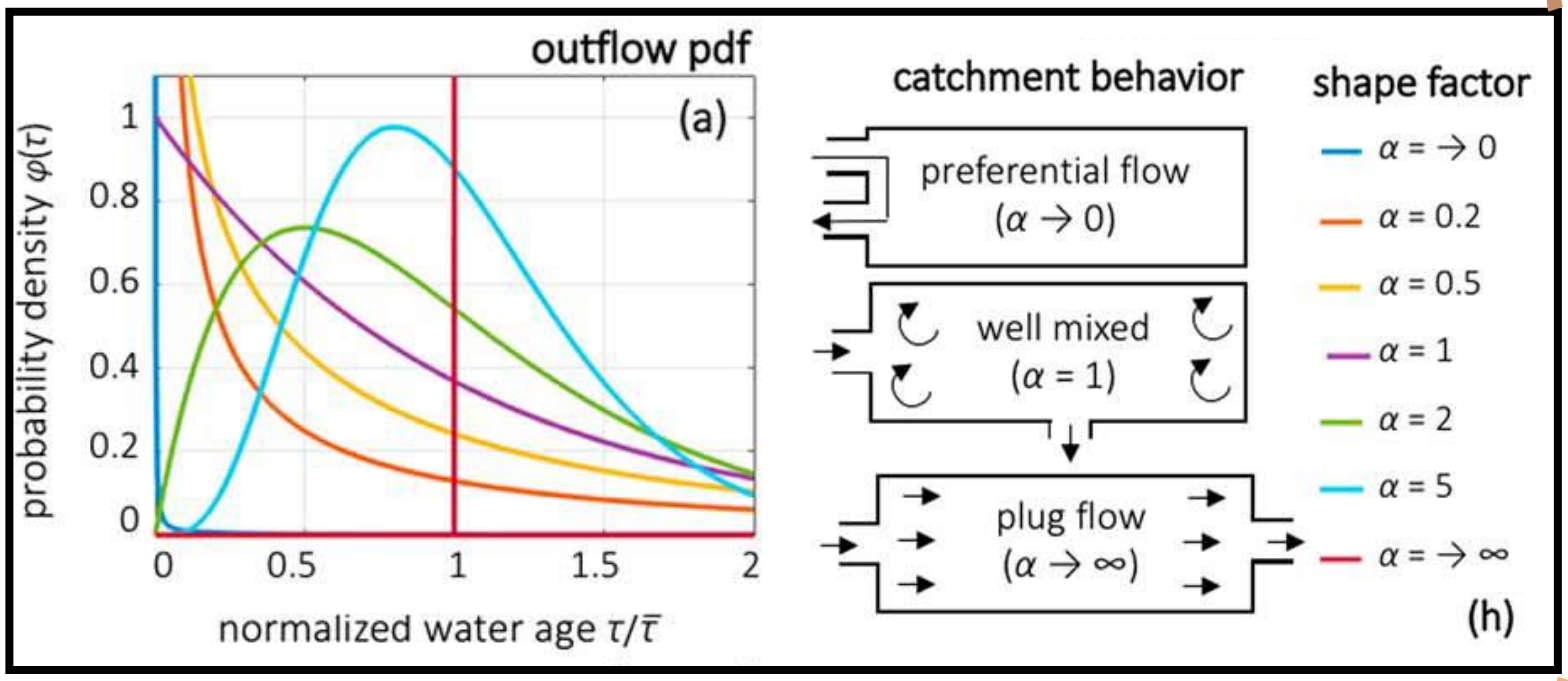

Berghuijs et al., GRL, 2017

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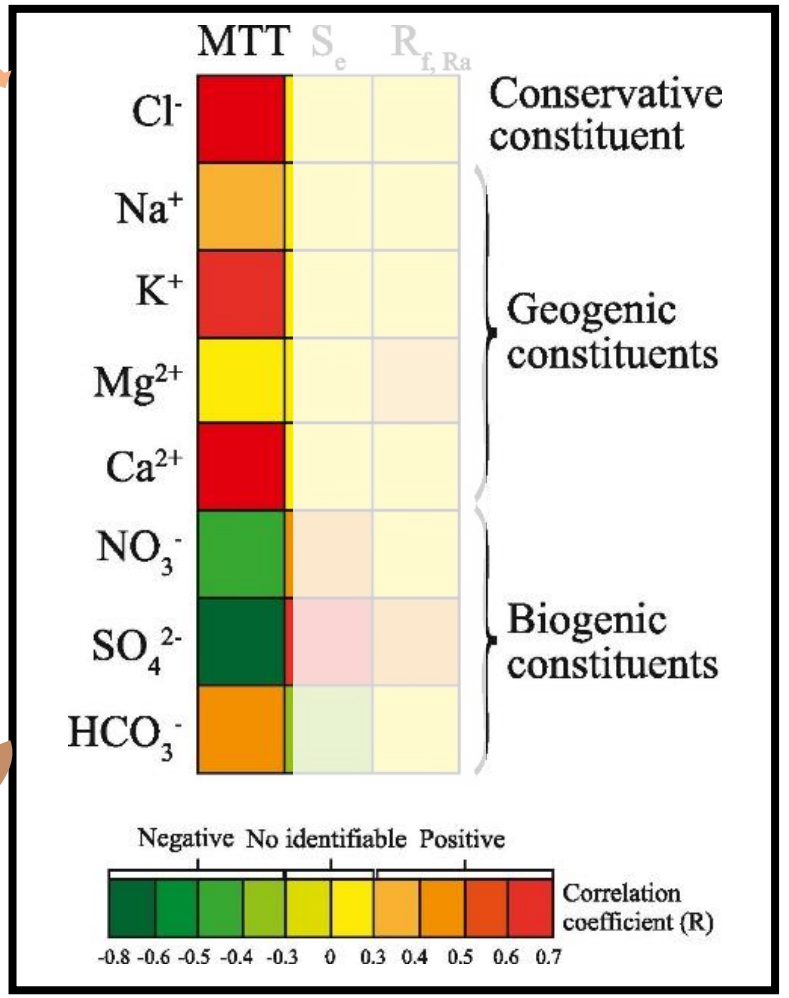
Chemical structure at the outlet of an aquifer:

- At first order, correlation between transit time and chemistry



Luo et al., JoH, 2019

How to account for aquifer Heterogeneity ?

Convoluted signature of ecohydrological and biogeochemical coupling

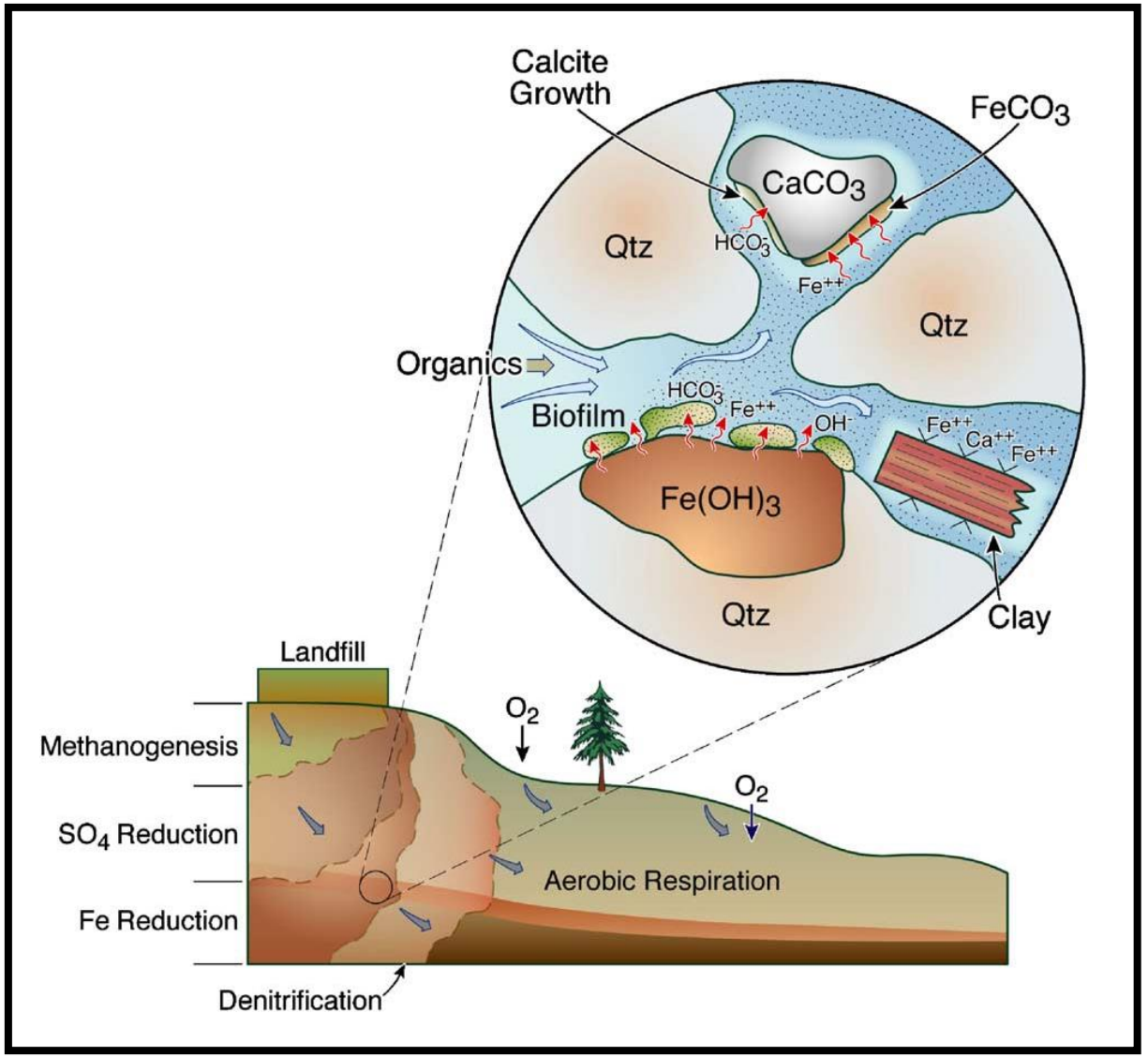
How to account for aquifer Heterogeneity ?

Convoluted signature of ecohydrological and biogeochemical coupling

Specificities of **reactive transport** in groundwater

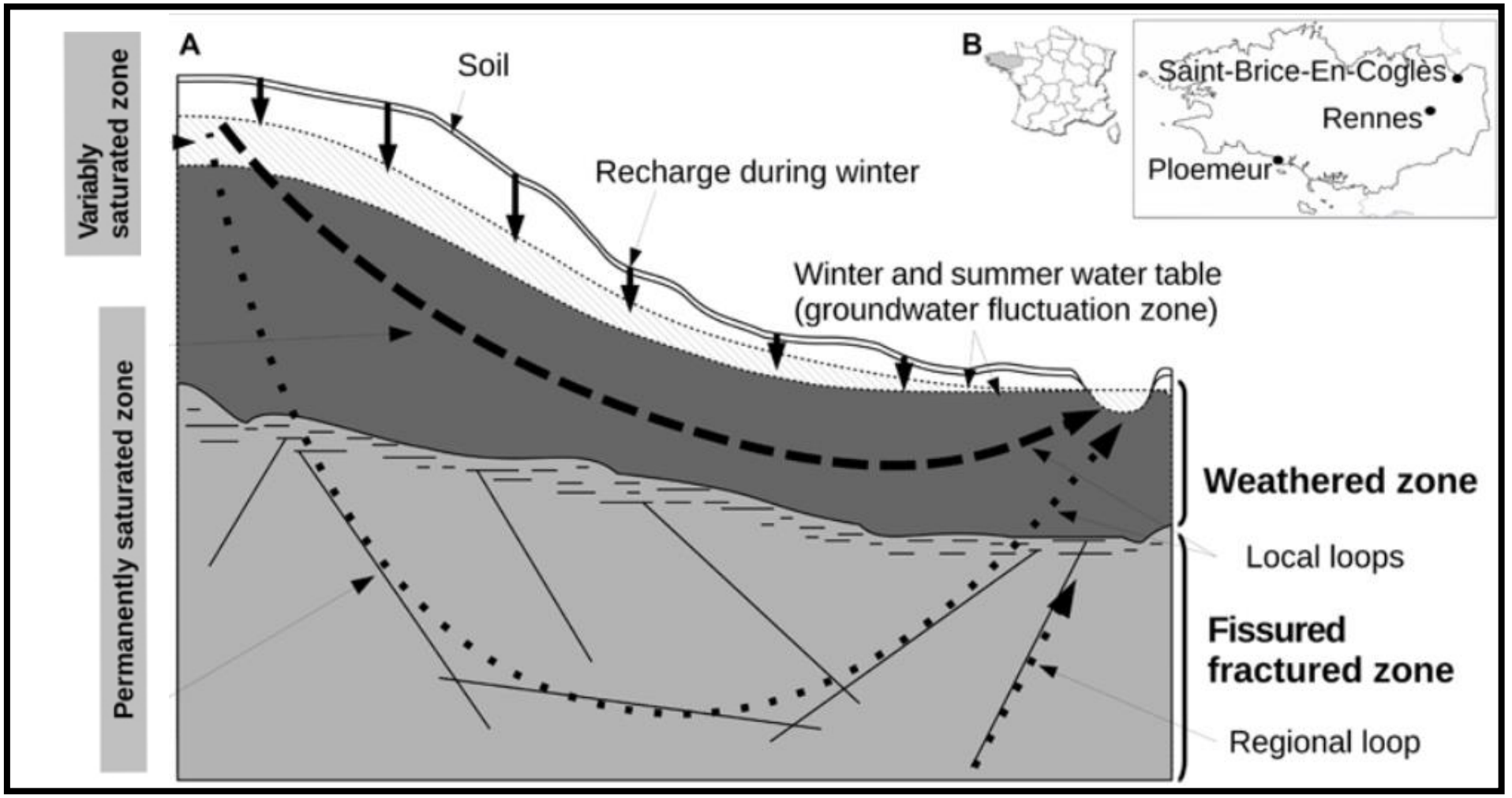
- Slow water flows
- High water-rock interactions
- Heterogeneities facilitate **micro-zones**
- Strong redox gradients
- Microbe-mediated processes

Importance of **interfaces** or **hotspots** in reactive processes and feedbacks ?



Steefel et al., EPSL, 2005

Fractured aquifers: Heterogeneity yields Reactive Barriers



Ben Maamar et al., 2015

- Extreme spatial variability in hydraulic conductivity
- The weathering front is a reaction interface
- Connectivity between fractures are reaction interfaces
- Crystalline rocks ~ 35% exposed rocks *(Suchet et al., 2003)*

Why Guidel ?

- River strongly influenced by GW discharge
- Catchment with high iron-based reactivity observed both in surface waters and in groundwater
- Enhanced mixing along fractures
- Iron and oxygen dependent micro-organisms revealed at high depths (70m)

Deep Groundwater

Shallow Groundwater

Biofilm

$$4Fe^{2+} + 10H_2O + O_2 \rightarrow 4Fe(OH)_3 + 8H^+$$

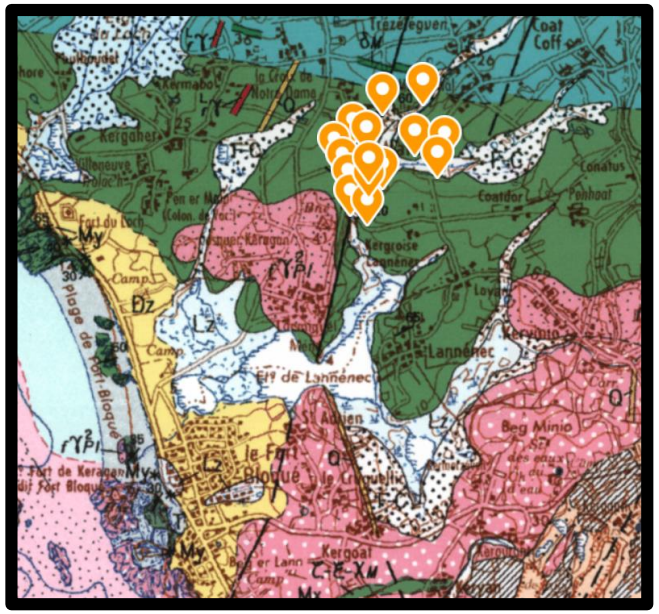
Mixing

Bacteria

Bochet et al., Nature Geosciences (2019, in press)

Hypothesis: Transient interface reactivity strongly affects Catchment-scale reactivity

Study site: Guidel



- Highly monitored catchment
- Observed deep microbial reactivity

Tools: Geochemical tracers

- Dissolved gases

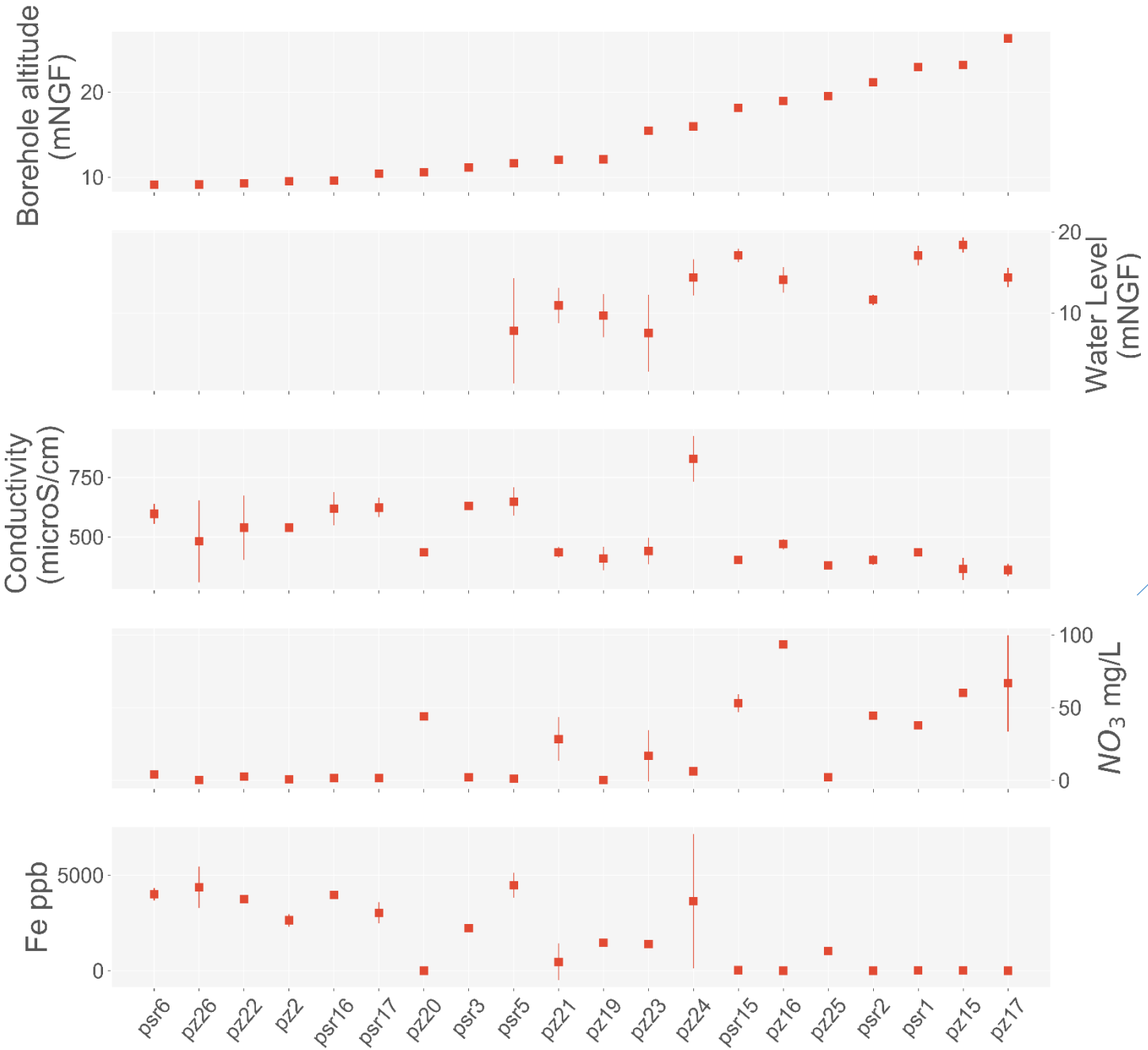
Dating tools

Conditions during recharge

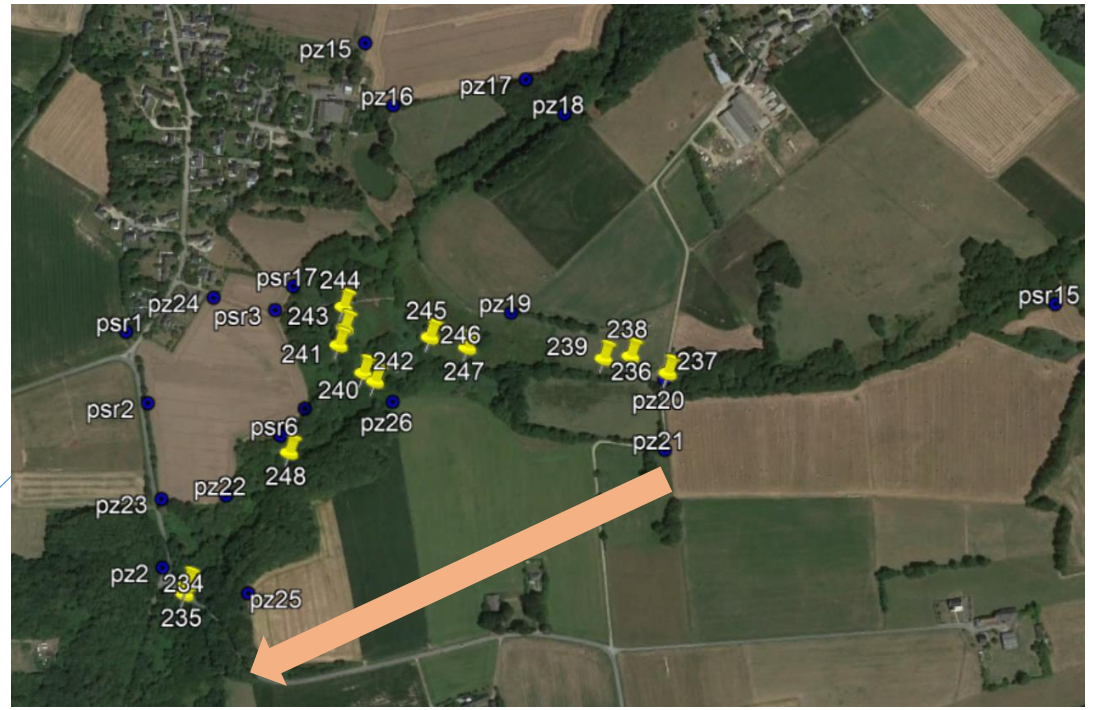
Reactants or Products of biological reactions

- River and groundwater chemistry
- In situ continuous measurements of DO with high precision probes

Structure of flows and Chemistry at Guidel



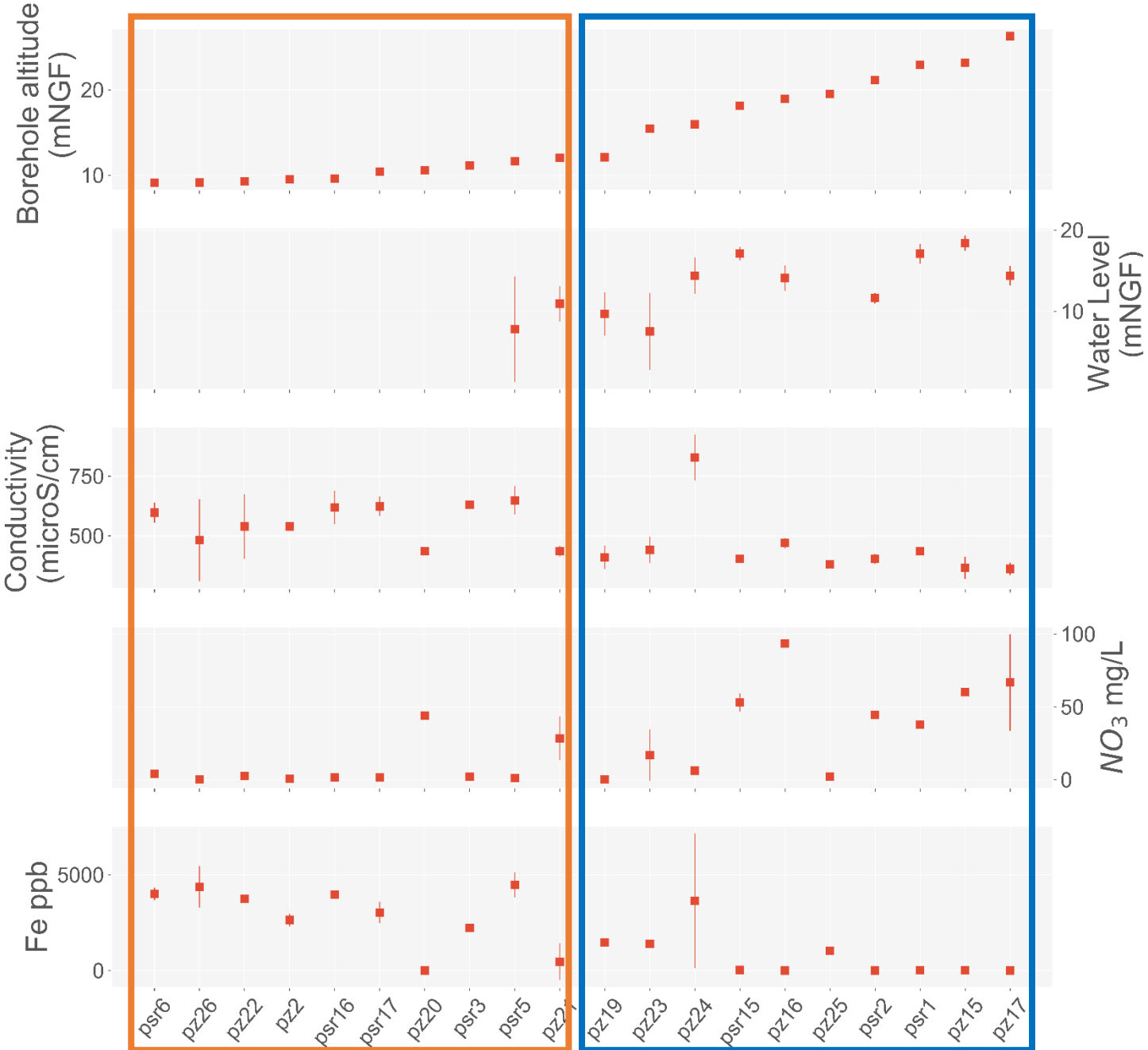
Bi-annual monitoring since 2017



Q x 2

1km

Structure of flows and Chemistry at Guidel



Converging aquifer

Discharge zone

Conductivity

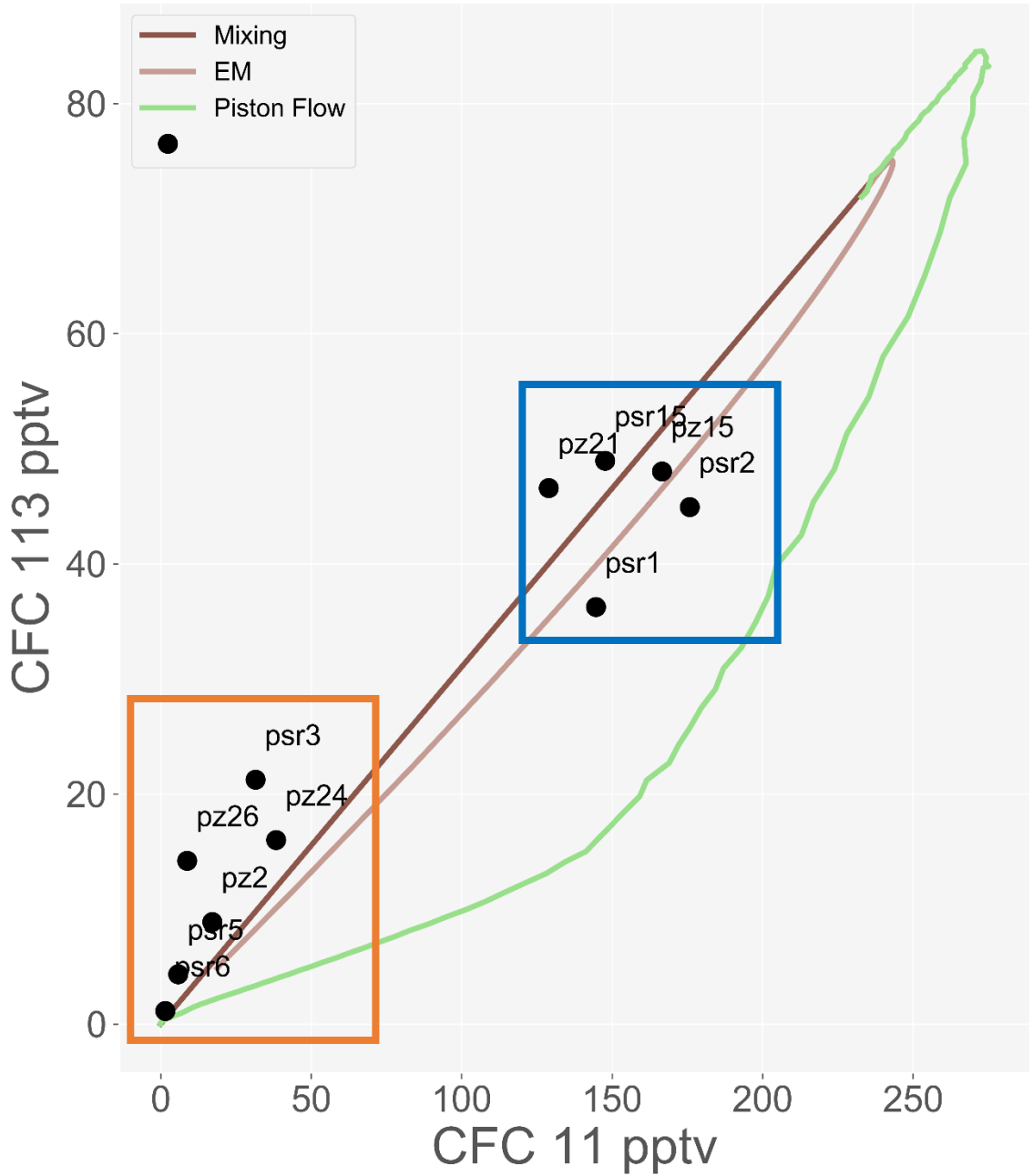
Fe, NO_3

Recharge zone

Conductivity

Fe, NO_3

Structure of flows and Chemistry at Guidel



Converging aquifer

Discharge zone

Conductivity

Fe, NO_3

CFCs, He,

O_2

Recharge zone

Conductivity

Fe, NO_3

CFCs, He

O_2

Structure of flows and Chemistry at Guidel

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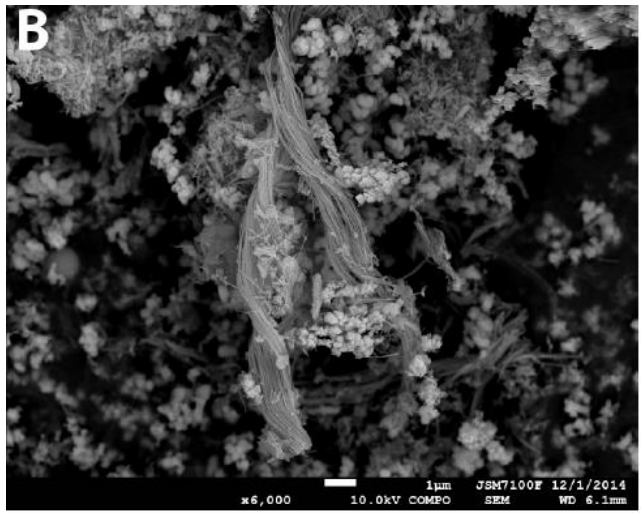
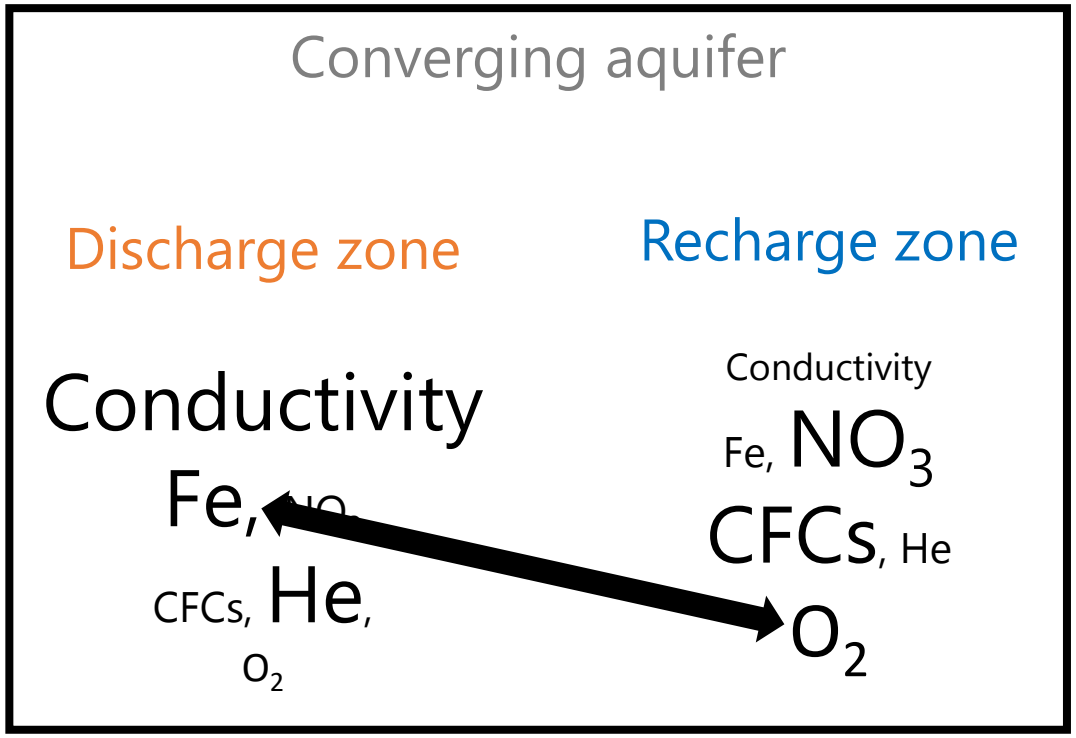


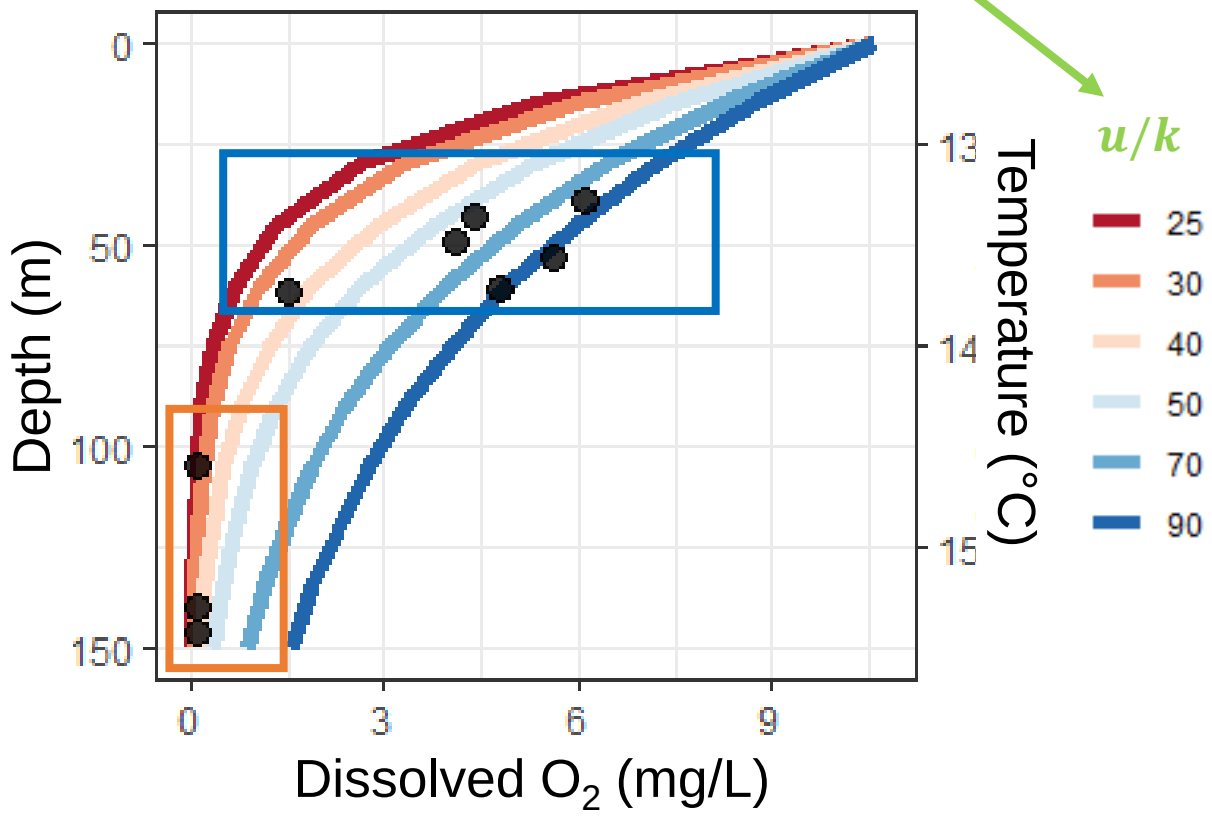
Bochet et al., Nature Geosciences (2019, in press)



In the river and within the aquifer !

Distribution of dissolved O_2 in Guidel groundwater
« effective » reactivity

$$[O_2] = [O_2]_0 \cdot \exp\left(-\frac{z}{sin\theta} \cdot \frac{k}{u}\right)$$



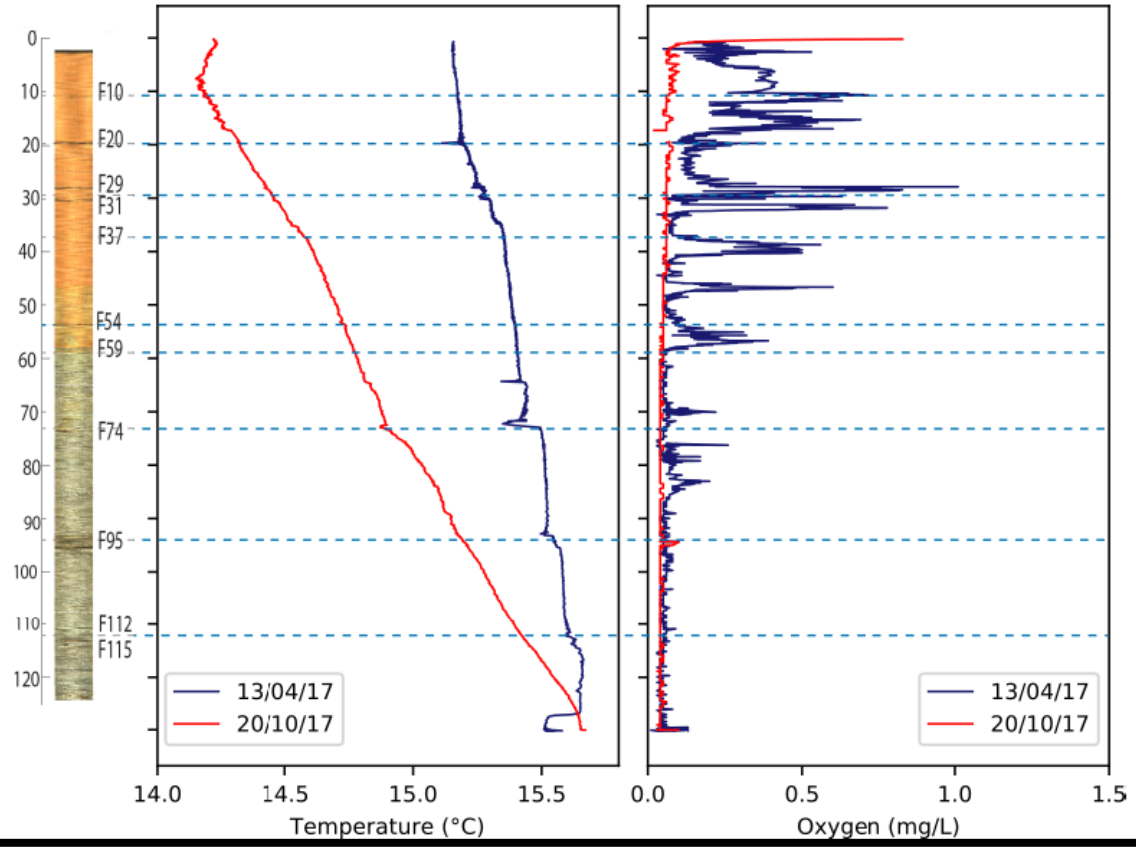
$$Da = \frac{\text{advection time}}{\text{reaction time}}$$

Da — $[O_2]$ constant

Da — $[O_2]$ varies with flows

Ivan Osorio, master student

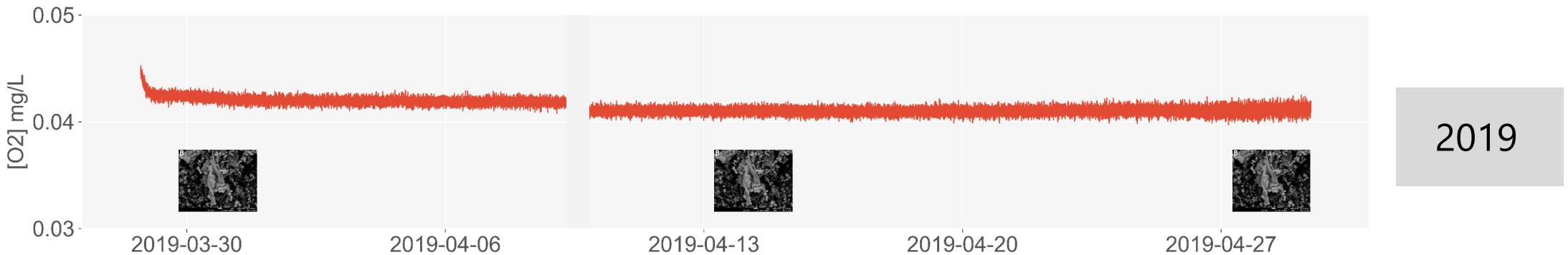
Temporal Distribution of dissolved O_2 in Guidel groundwater: the case of PZ26



2017

Hot-moments of detectable O_2 through fractures

\+ always deep O_2-dependent microbial life



2019

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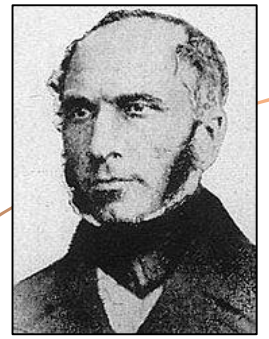
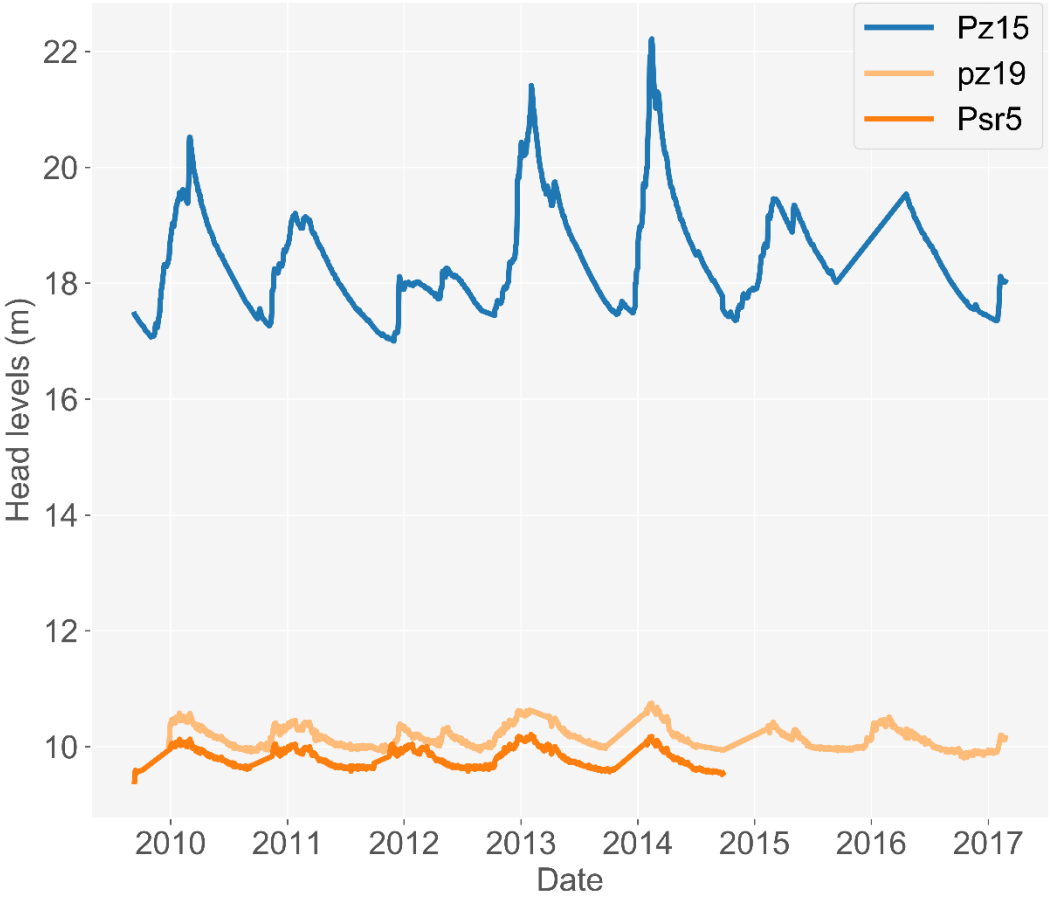




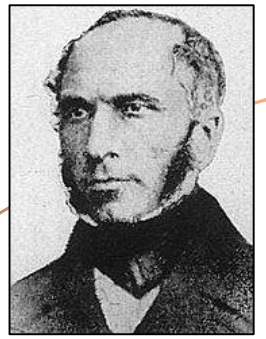
Distribution of flow velocities

Transient transit time distributions
for **a water particle** to travel from recharge to discharge

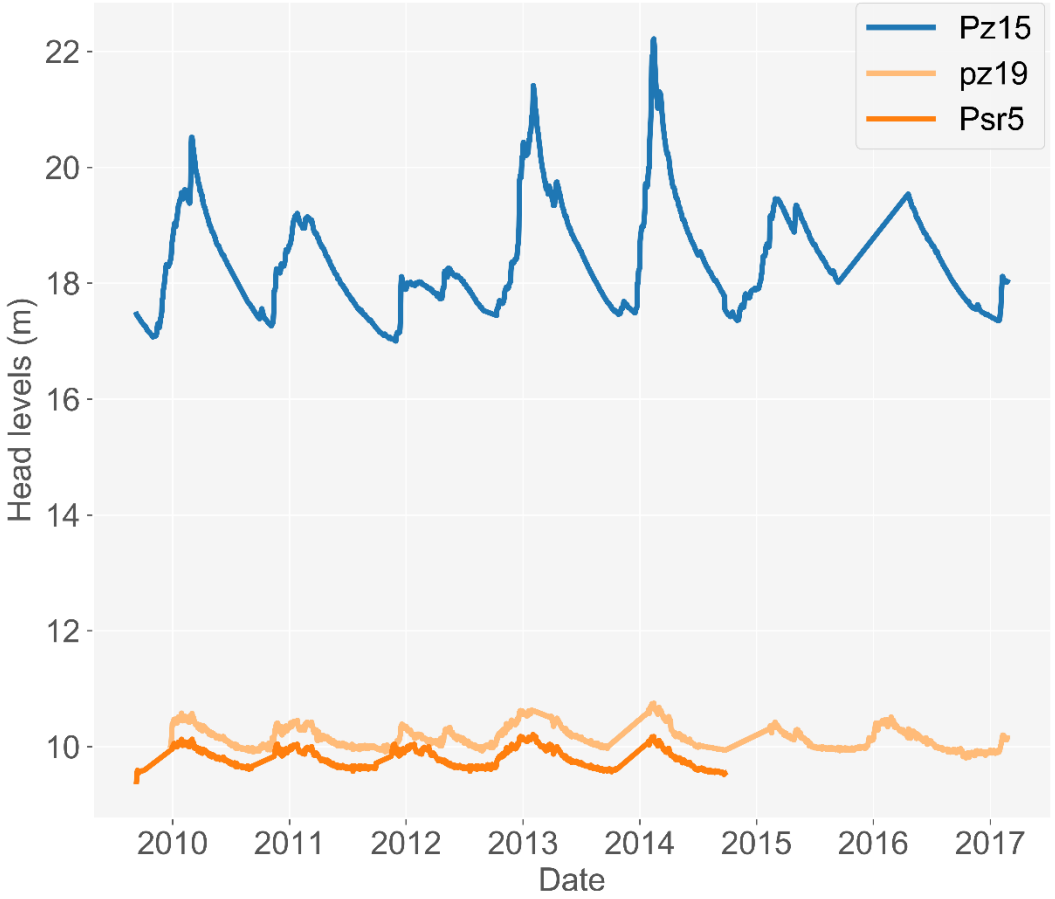
First order kinetics

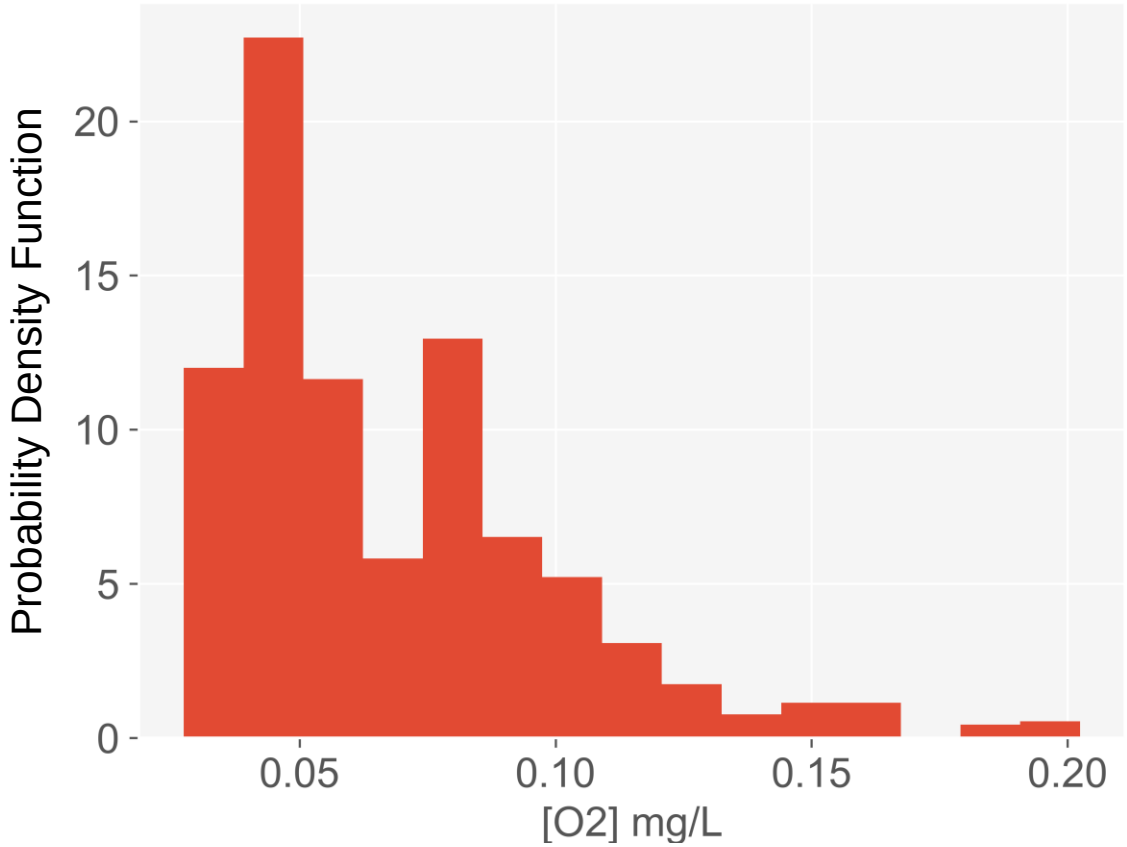
Transient distributions of **O_2 concentrations**
at the intersection of fractures

Temporal Distribution of dissolved O_2 in Guidel groundwater: the case of PZ26



Distributions of **O_2 concentrations**





Conclusion and Perspectives

- « Background » reactivity controlled by the availability of electron donors and acceptors
- « Hot-spots and hot-moments » reactivity controlled by transport processes, i.e. extreme events that rapidly bring and mix fluids with different transit time and geochemical compositions
- Deep reactions : microbe-mediated and highly sensitive to rapid hydrological changes
- The relevant time frame for reactivity, « contact » time?
- In situ estimation of reaction rates by fractured-located tracer tests to mimic intermittent O_2 impulses.