# Third ENIGMA ITN meeting

## Lausanne – 09 & 10 February, 2018

***ENIGMA*** *Innovative Training Network :* **European training Network for In situ imaGing of dynaMic processes in heterogeneous subsurfAce environments**

Work Package – WP4

Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids

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ESR 10: Peleg Haruzi

ESR 11: Richard Hoffmann

ESR 12: Satoshi Izumoto

Supervisor: Niklas Linde

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# Common main questions + Objectives of WP 4 I

| Parts of WP 4 - copy from grant agreement<br>Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids | | |
|---|---|---|
| 4.1 | Laboratory facility: geophysical millifluidic lab for validating emerging geophysical techniques for monitoring transport and reaction processes | Month 36 |
| 4.2 | In situ datasets that couple tracer experiments and geophysical monitoring | Month 48 |
| 4.3 | Report on process bases geophysical methodologies to monitor subsurface transport, mixing and reacting | Month 36 |

| ESR PhD topic + Lead-Contribution for the Workpackage parts: | |
|---|---|
| For 4.1 | Development and improvements of geophysical signals for<br>⇒ ESR 9: Upscaling a framework to quantify spreading and mixing<br>⇒ ESR 12: Quantifying biochemical processes with SIP method |
| For 4.2 | Enhance transport imaging with new experimental strategies by improving (Field work possible):<br>⇒ ESR 10: High resolution of geophysical time lapse measurements (GPR-FWI)<br>⇒ ESR 11: Multiple tracer approaches complemented by Inversion and Simulations (BEL) |
| For 4.3 | ⇒ Exchange between all four ESR results as a kind „Summary“ report<br>- Improve petrophysical relations<br>- Optimize a tracer test by adjusting tracer properties<br>- Analyze and derive transport processes by subtraction of time-lapse geophysical signals / plane images. |

# Common main questions + Objectives of WP 4 II

*Main Questions:*

1. How to improve transport process imaging in the subsurface with new experimental and simulation strategies?
2. How can we track the transport of chemical species and detect biochemical reactions with geophysical methods ?
3. How can we optimize the tracer detectability using the geophysical methods?
4. How synchronize improving imaging resolution with upscaling
5. What are the quantitative relations between measured geophysical properties and tracer characteristics ?

*Challenges:*

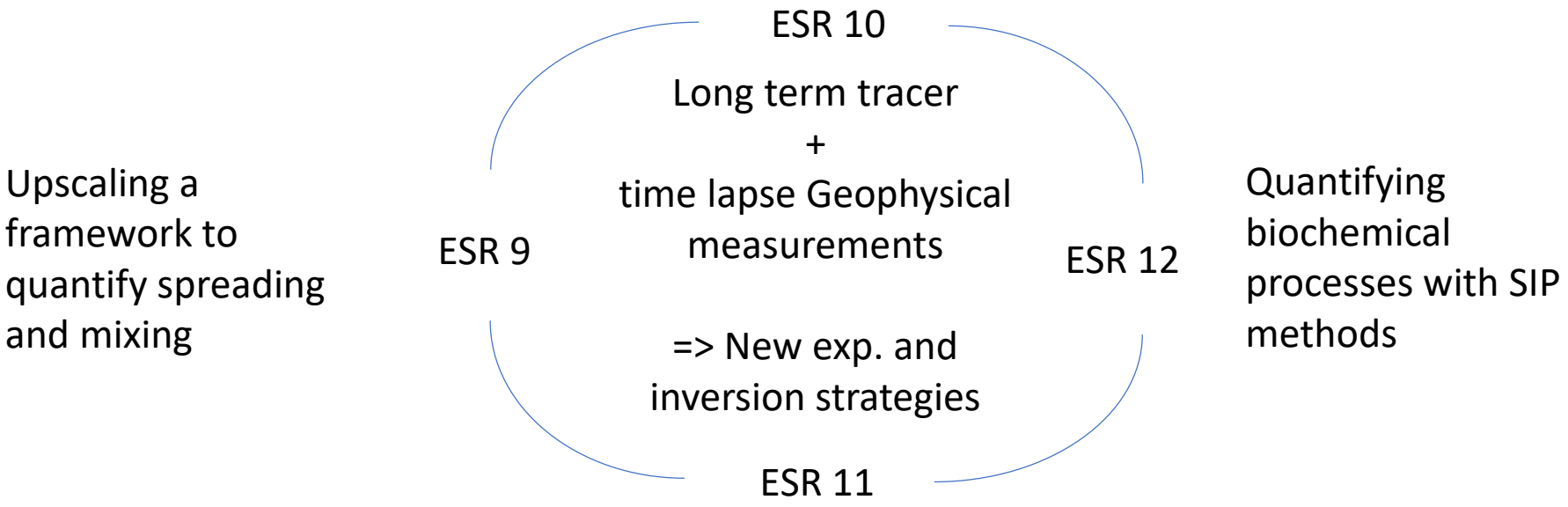
1. Understanding below-resolution heterogeneity of tracer on bulk geophysical parameters
2. Density effect of tracer plume + geophysical scale signature of small scale processes
3. Monitor mixing and (bio-)reaction processes in the field

# Interactions between the four PhD-projects

Joint experiments like a Joint/multiple tracer approach complemented by geophysical tools (WP4.2)

suggested ENIGMA experts: Niklas Linde, Tanguy Le Borgne, Sander Huisman, Olaf Cirpka

Increase/Improve the Resolution of geophysical time lapse measurements (e.g. GPR FWI)




Sites + Models => Alluvial: Hermalle-sous-Argenteau ; Fractured: Mons
Choose a Tracer with different diffusion coeff. => Solute/Heat/Reactive/(Dissolved Gas)

# Reviewlet

**Recent advances for imaging transport and chemical reactivity in the subsurface on multiple scales**

Tracer techniques --- Biofilm --- Geophysical measurements/ 4D time lapse --- Inversion / Simulation

**Existing papers (example):**

Binley, Andrew, et al. "The emergence of Hydrogeophysics for improved understanding of subsurface processes over multiple scales." Water resources research 51.6 (2015): 3837-3866.

Atekwana and Slater (2009) Biogeophysics: a new frontier in earth science research, Rev. Geophys., 47.

**Positioned compared to other:**

Current methods/Solutions have a strong potential for going a step further with Improvements

=> Summarize this „Potentials“ as basis with innovative possibilities for new results afterwards (e.g. WP)

**Organization related to the timeframe?**

1. Collect main important literature for predefined subsections based on each PhD motivation for the framework
2. Create concise connections between the subsections ( + view on WP) as consensus of each PhD topic
3. Outwriting of each subsection + refinements and reviewing by each ESR first

# Review article – general workflow

The purpose of the flowchart is to explain the motivation and simplify the strategy

WP4: Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids

**Motivation**:
What are the transport characteristics of a solute in the subsurface?
**Transport and reactive characteristics** (they are also parameters): Dispersion, decay, retardation, production, (mixing ?)

**Inject a tracer or biochemical sample** to the subsurface or to a lab sample. Tracer type may be conservative or not.
Examples: inorganic salts, fluorescent, organic anions, radio-isotopes, heat.
Characteristic variable.

**Transport processes in the subsurface:**
(physical, chemical, biological):
Advection, diffusion, dispersion, sorption, chemical and biochemical reactivity, radio-active decay.

**Spatio-temporal hydrogeological parameters**: ϕ, K, C, s (salinity), T, θ

**Time-lapse monitoring**

**Observation using geophysical methods**:
1. Geophysical methods: GPR, SIP, ERT, DTS, seismic, …
2. Wells multi level sampling
3. Laboratory methods: PIV, heat probes

**Spatio-temporal measured dataset**:
Wave time arrival and intensity, resistivity, amplitude of images, well log data, temperature, …

**Spatio-temporal geophysical parameters**:
ε, σ, ϕ (phase), Z (seismic impedance)

**Petrophysical relations for quantitative analysis**:
transformation of measured geophysical parameters to hydrogeological parameters (and vice versa)

**Data processing and analysis**:
1. Inversion approaches:
   - Geophysical inversion from measured dataset to derive geophysical parameters.
   - Joint/coupled inversion from measured datasets to derive hydrogeological and/or transport parameters
2. Spatial and temporal moments of dataset of tracer property (concentration, temperature, or their fluxes).
3. Forward modeling

**Challenges**:
- Understanding below-resolution heterogeneity of tracer on bulk geophysical parameters
- Density effect of tracer plume
- Monitoring biochemical reaction

**Outlook**:
Improve physical understanding of EM and seismic waves interaction with tracer and soil

* Interpretation of transport processes to be done in regards to the scale of the monitoring domain