New technology development for CO_2 storage

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British Geological Survey

ENOS

Enabling Onshore Storage in Europe

Why are new/improved monitoring technologies needed?

Improvements and innovations to sensors and monitoring strategies enable project operators to verify that the site is meeting requirements while increasing efficiency, safety (and reducing costs)

How do we advance technologies/techniques?

- Improve understanding of processes or response of the subsurface/at surface to improve efficiency of monitoring
- Improve sensitivity, reliability, repeatability of technologies & techniques
- Reduce cost of deploying sensors (lower cost tools, more efficient data handling/processing/interpretation, lower maintenance, greater longevity)

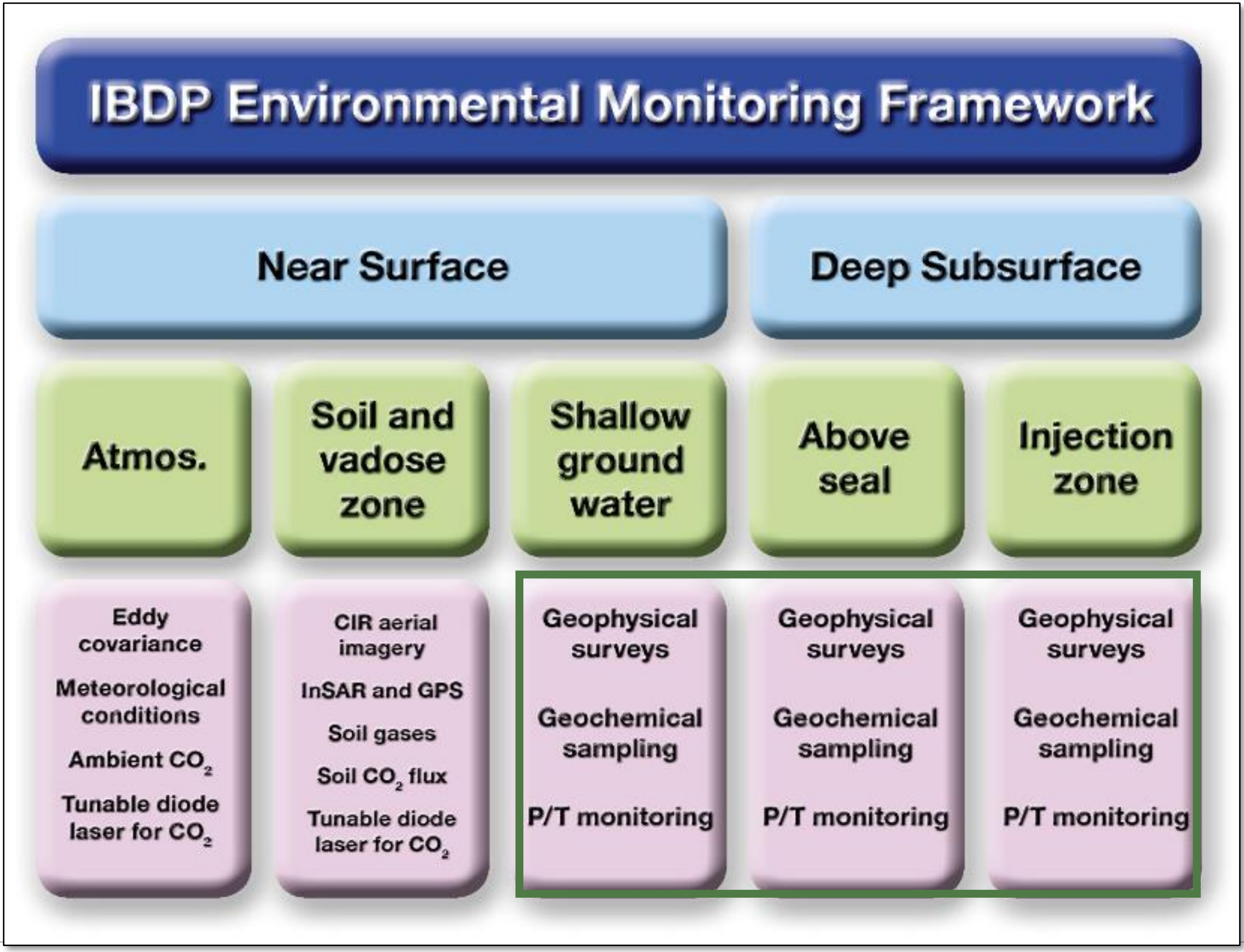
Outcomes from ENOS WP3 stakeholder workshop (26/4/18)

- Onshore monitoring technology development needs identified by storage operators & ENOS tools presented

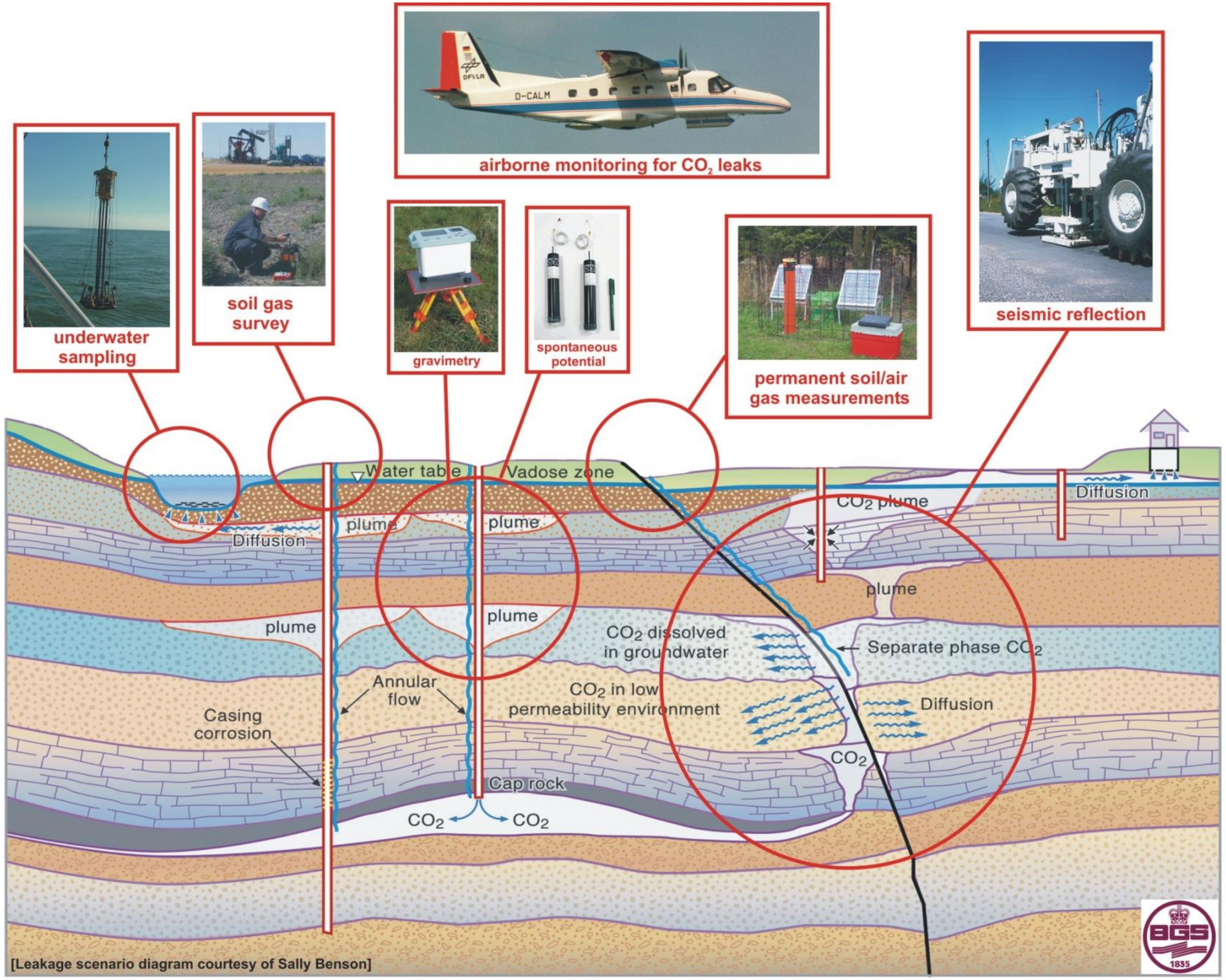
Key outcomes:

- Some common research needs identified by storage operators (e.g. cheaper, long-lasting tools, more efficient data handling, processing and interpretation….)
- Integration of different monitoring technologies essential, but monitoring solution will vary from site to site and over site lifetime

Example: Decatur project monitoring plan

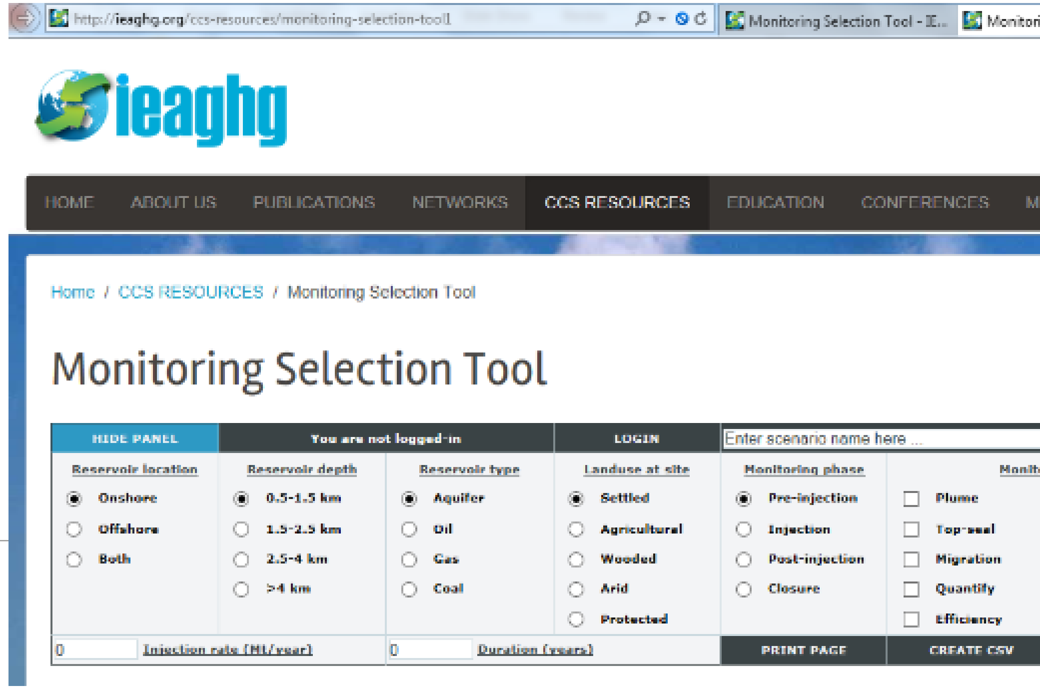


Monitoring tool selection



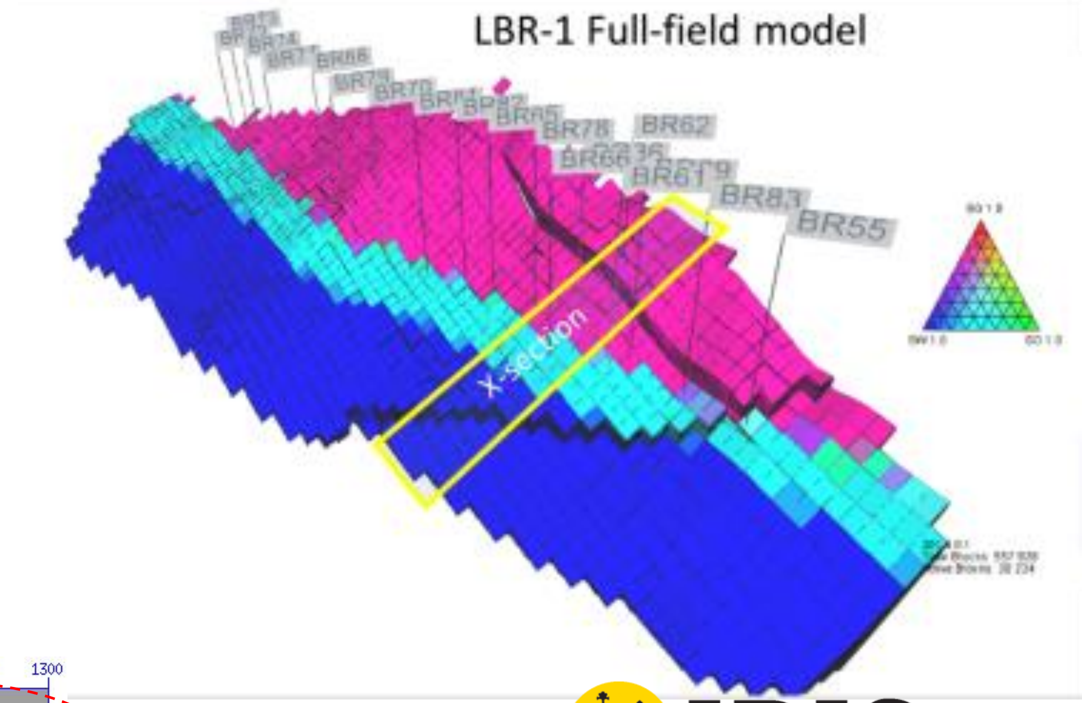
- A key challenge for storage site operators – what to choose?

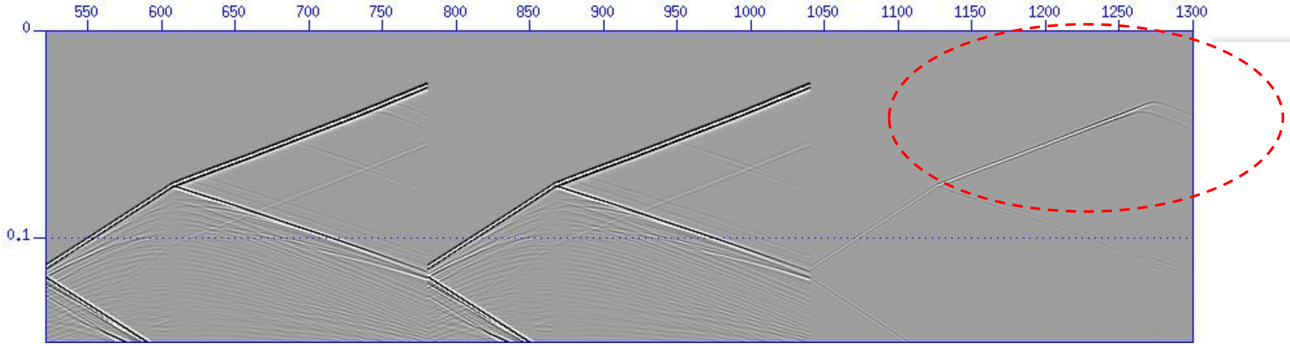
http://www.ieaghg.org/ccs-resources/monitoring-selection-tool1



Reducing risks & improving monitoring capabilities through design & planning

- Using improved understanding of potential leakage pathways (e.g. boreholes and faults) to improve monitoring strategies
- Modelling expected response of site (including potential leakage pathways)





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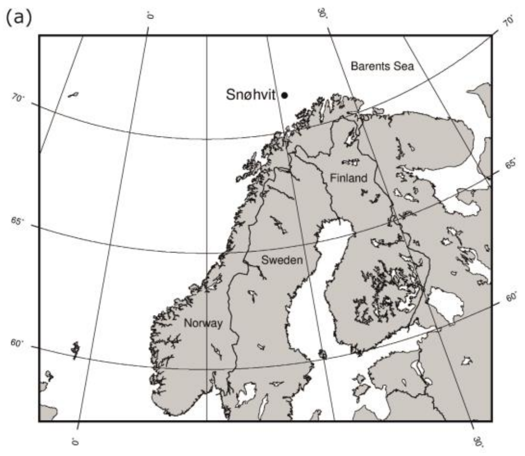
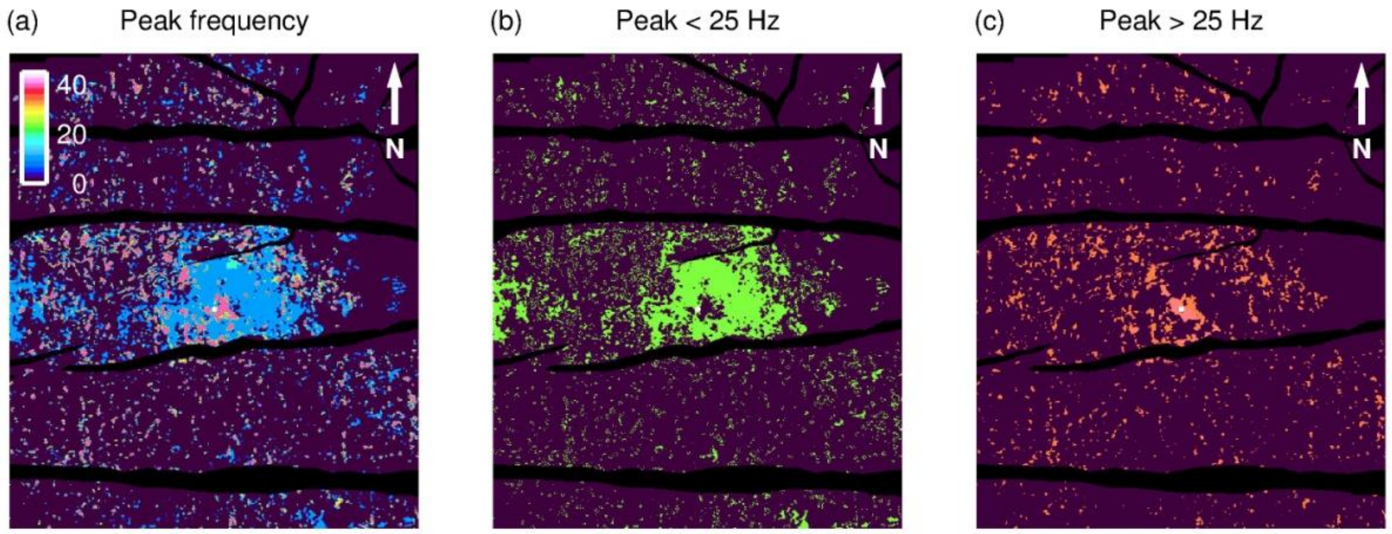
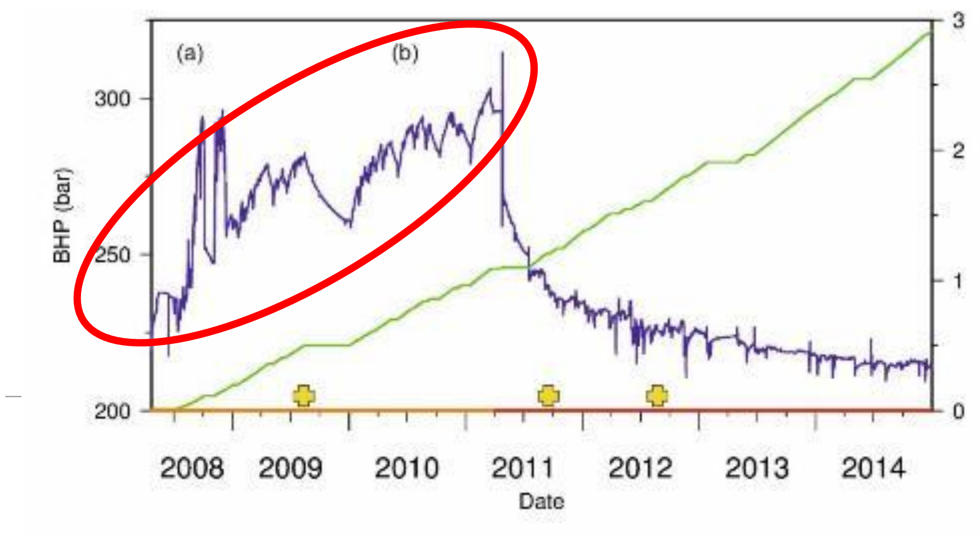
Time-lapse seismic monitoring at the Snøhvit Field



Downhole pressure data shows increasing pressure during initial injection phase – approaching estimated fracture pressure

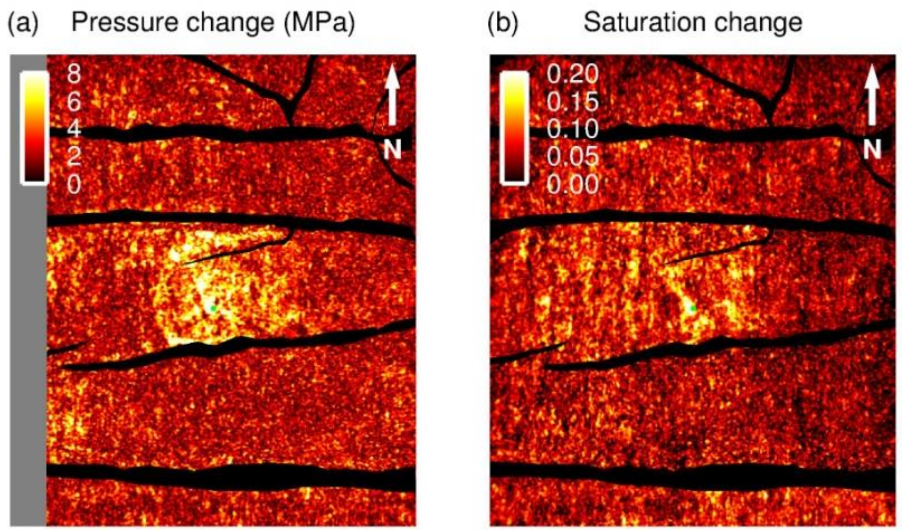




Top: discrimination of pressure and saturation changes using spectral decomposition of seismic data.

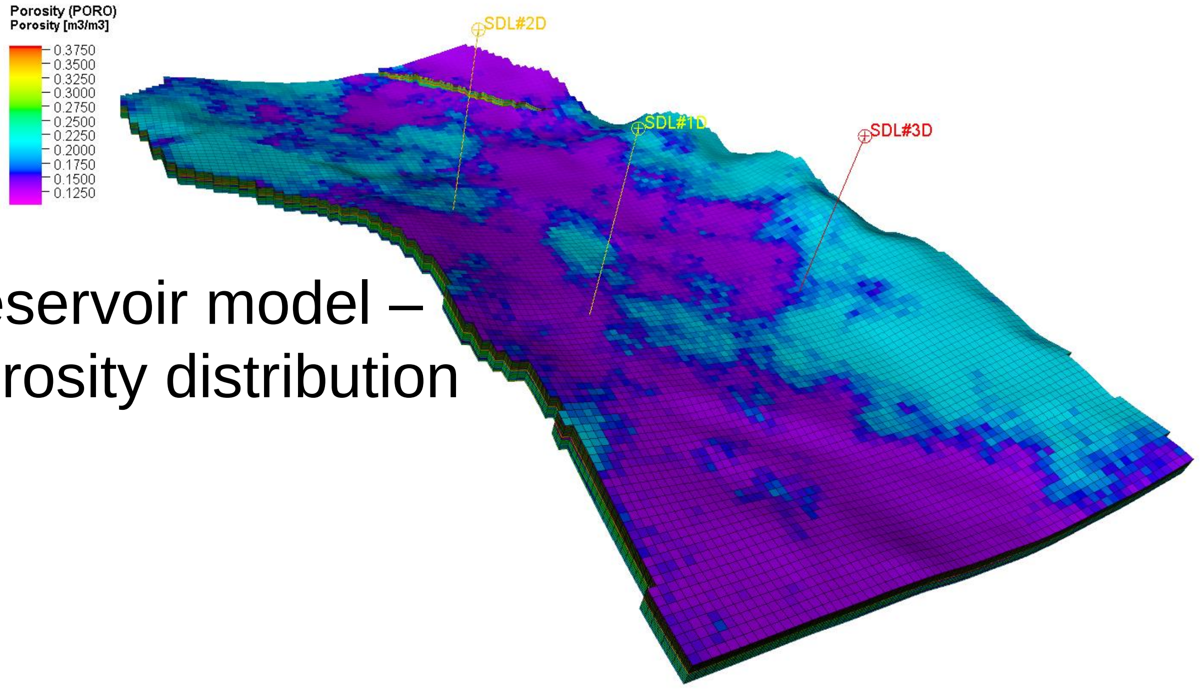
Right: The inverted pressure and saturation changes from Grude *et al.* (2013).

Results show a striking correlation.

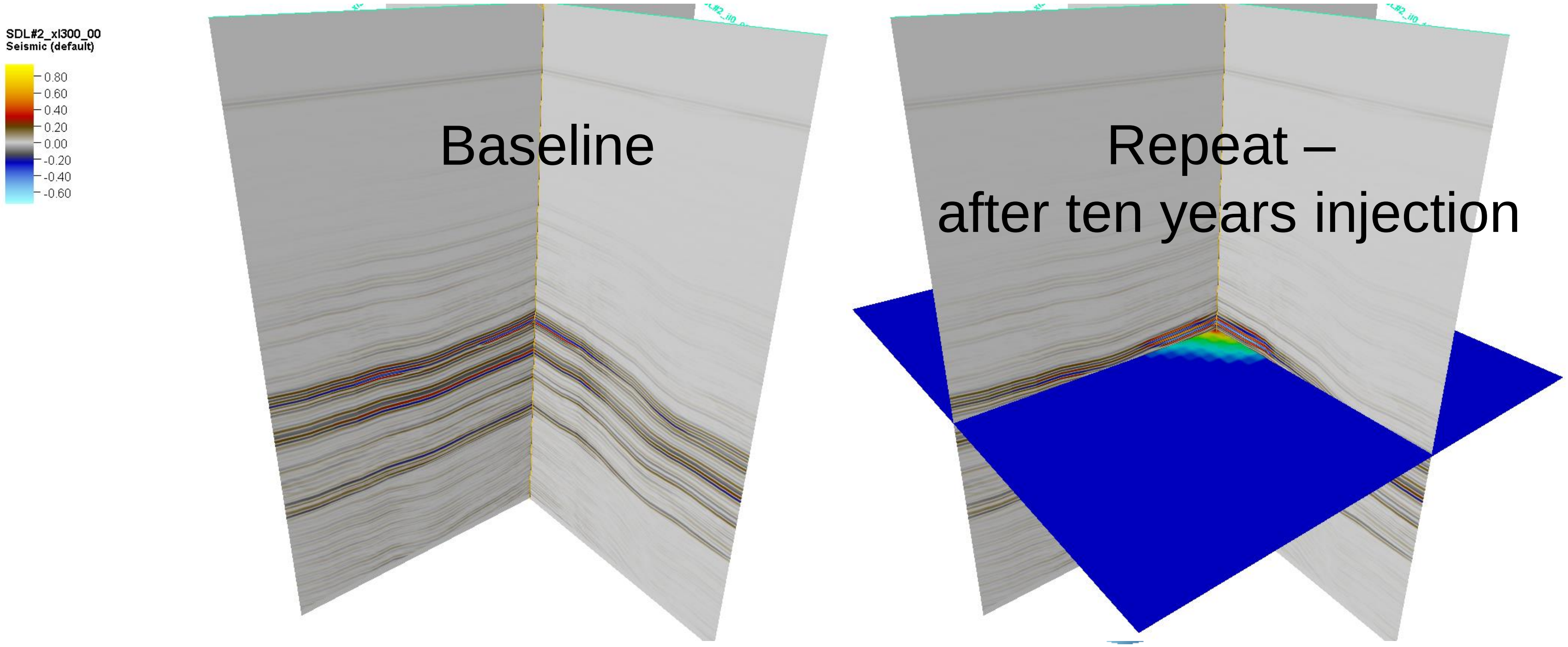


Compressive sensing

Compressive sensing techniques can use randomly sampled receiver positions to interpolate missing data and provide a possible cost effective technique for monitoring conformance.



Reservoir model – Porosity distribution

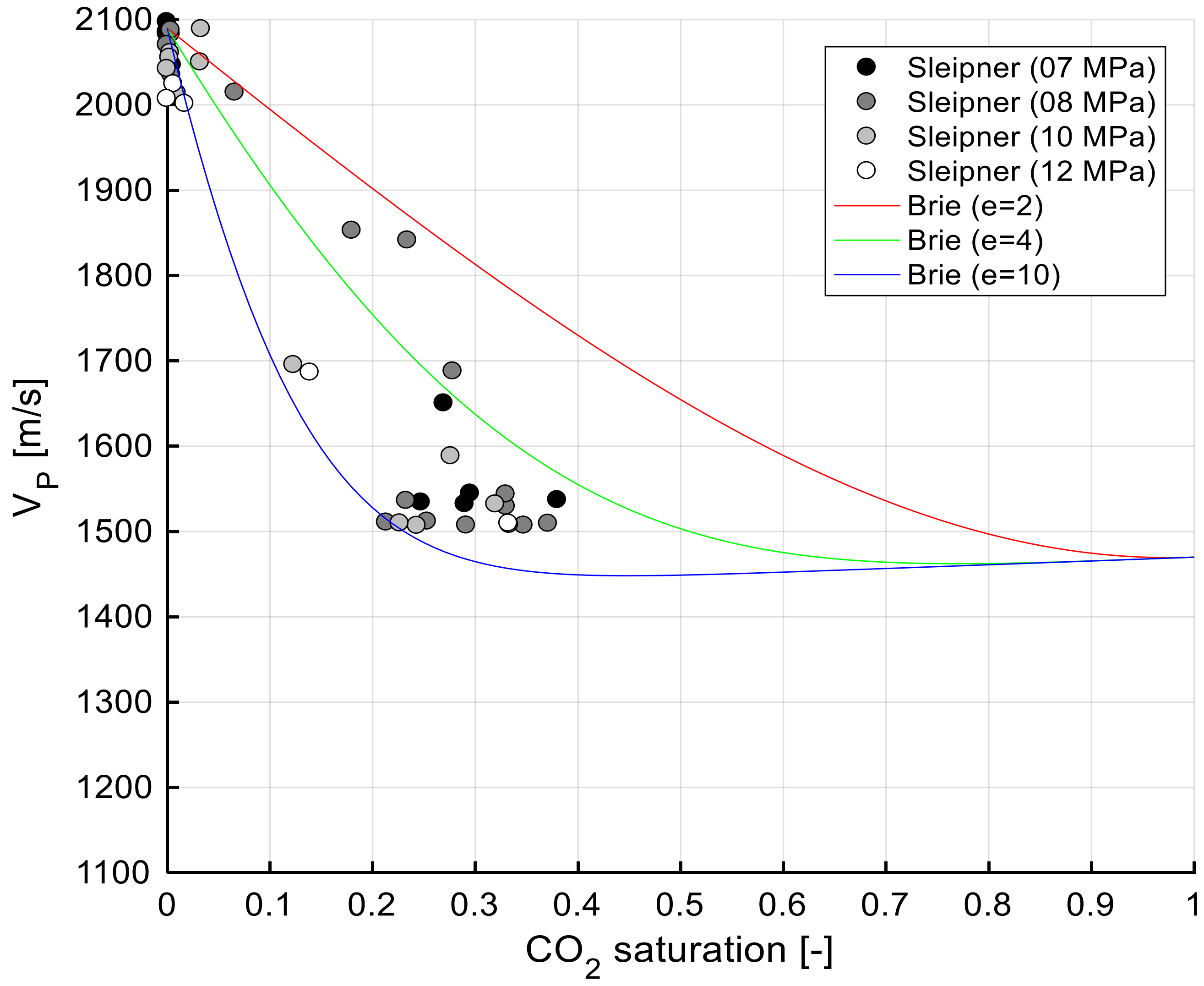


Baseline

Repeat – after ten years injection

Synthetic study of CO_2 injection – aligned to the Northern Lights project - testing the power of compressive sensing with curvelet transforms. The results are constructed from 20% of the usual receiver positions and offer a potential method for cost effective monitoring.

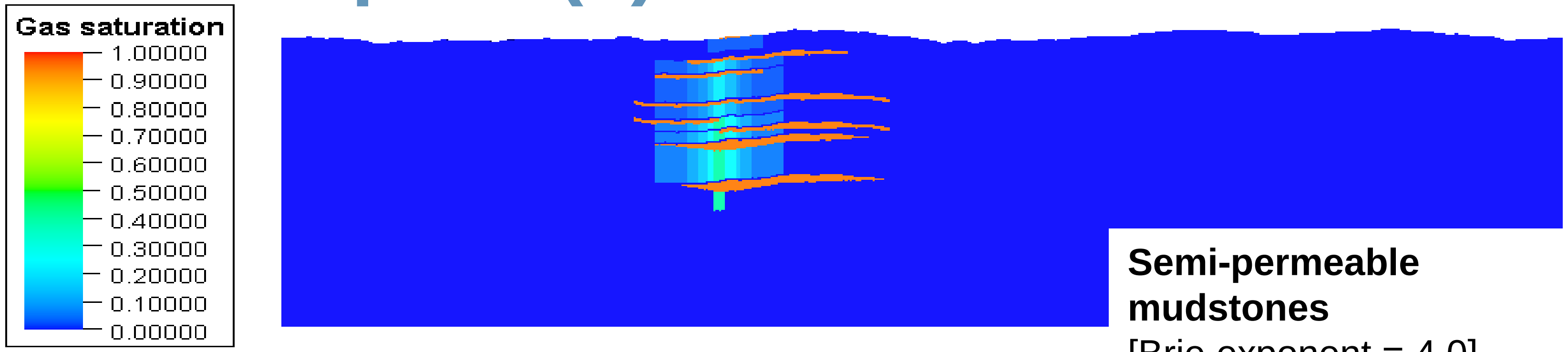
New rock physics data from Sleipner



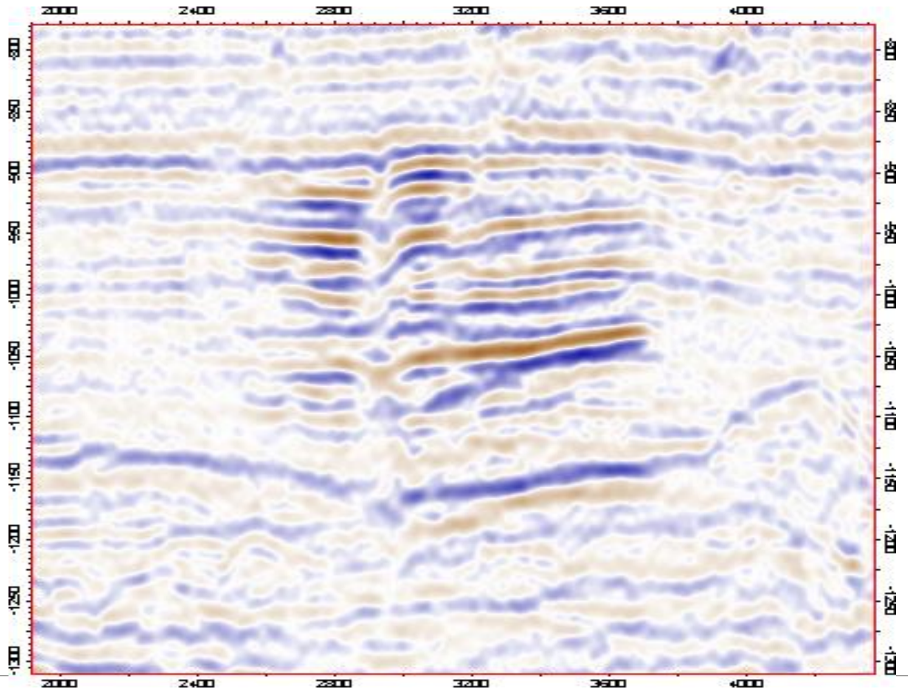
Utsira Sand laboratory measurements (DiSECCS project - Suarez et al. , 2017)

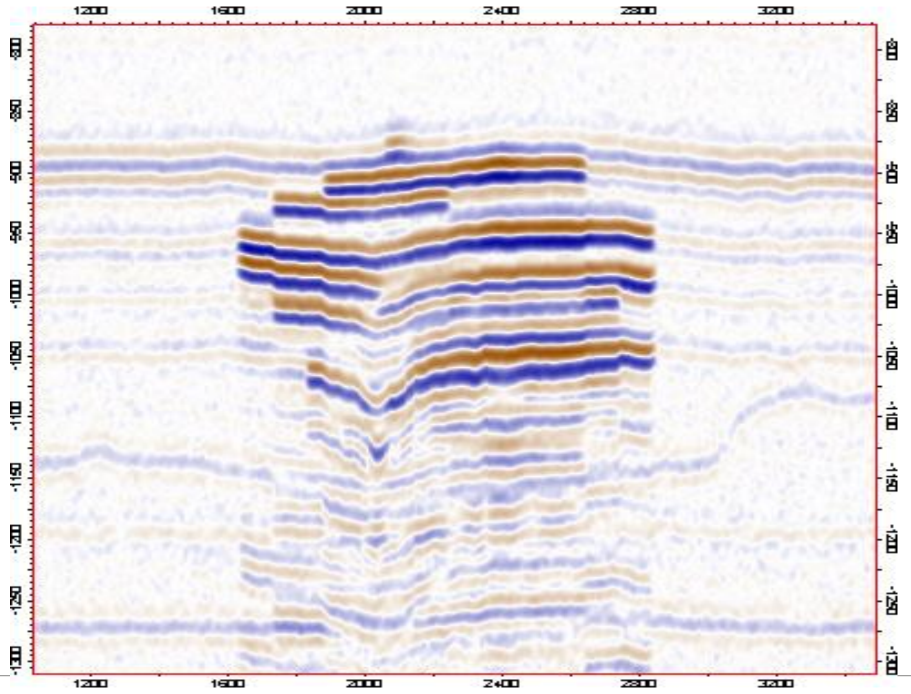
DiSECCS

Synthetic seismic modelling to explore migration mechanisms at Sleipner (1)



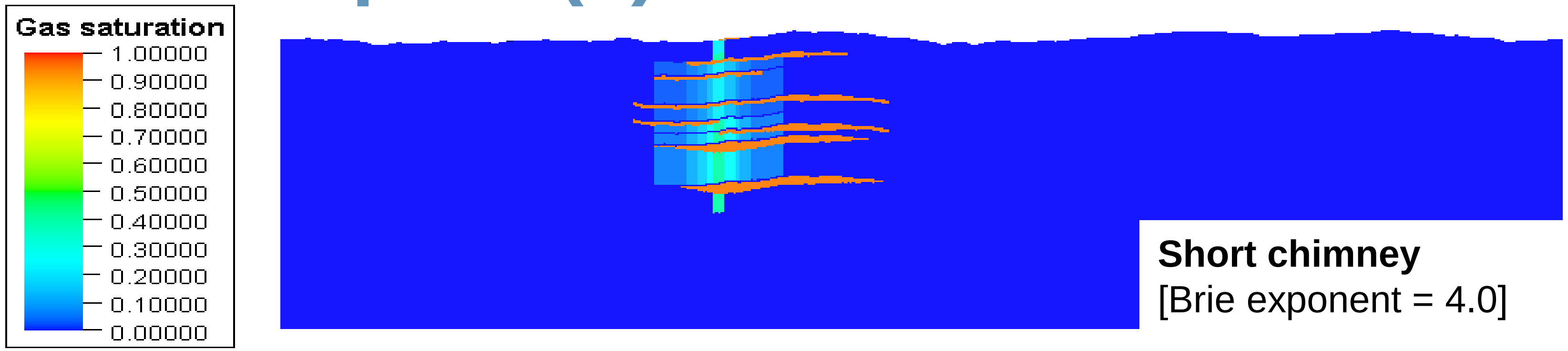
Semi-permeable mudstones
[Brie exponent = 4.0]



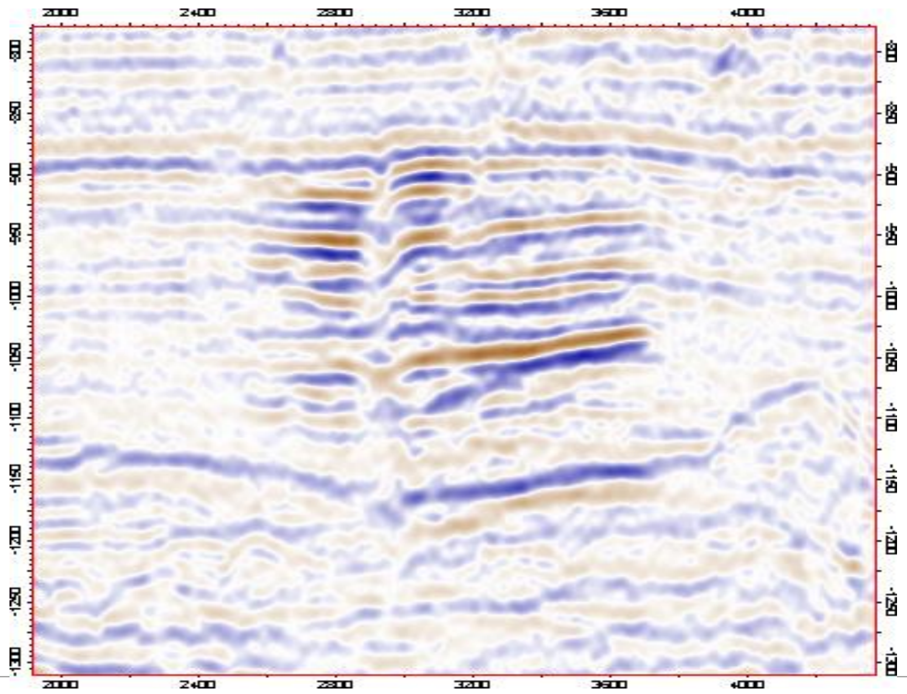


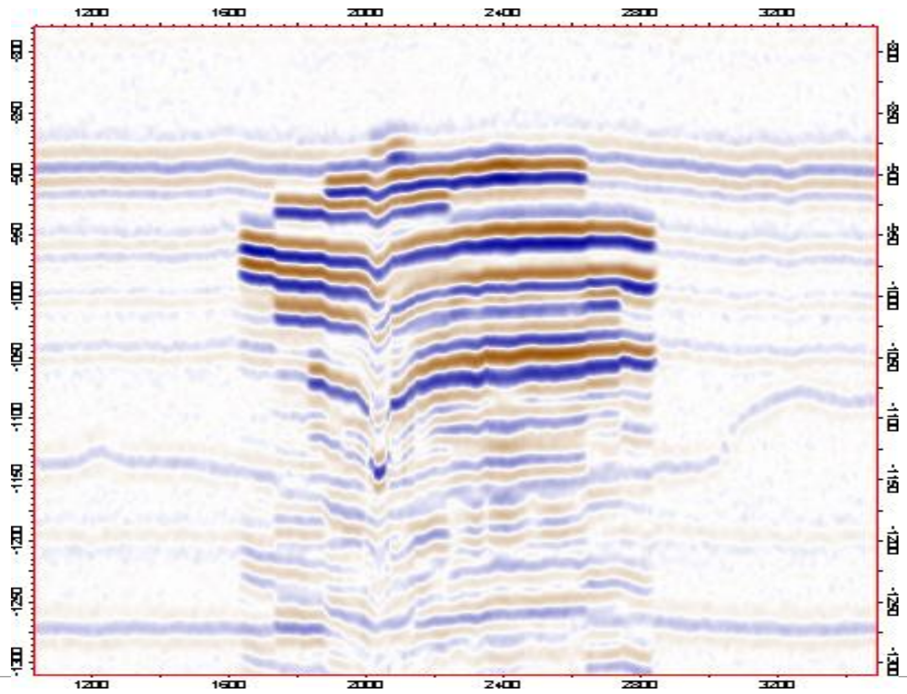
DiSECCS

Synthetic seismic modelling to explore migration mechanisms at Sleipner (3)



Short chimney
[Brie exponent = 4.0]





DiSECCS

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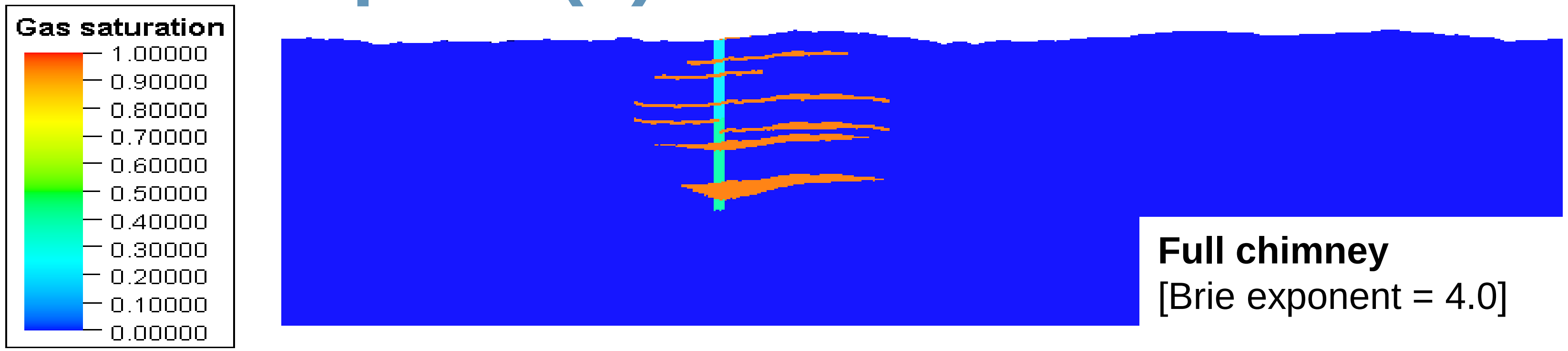

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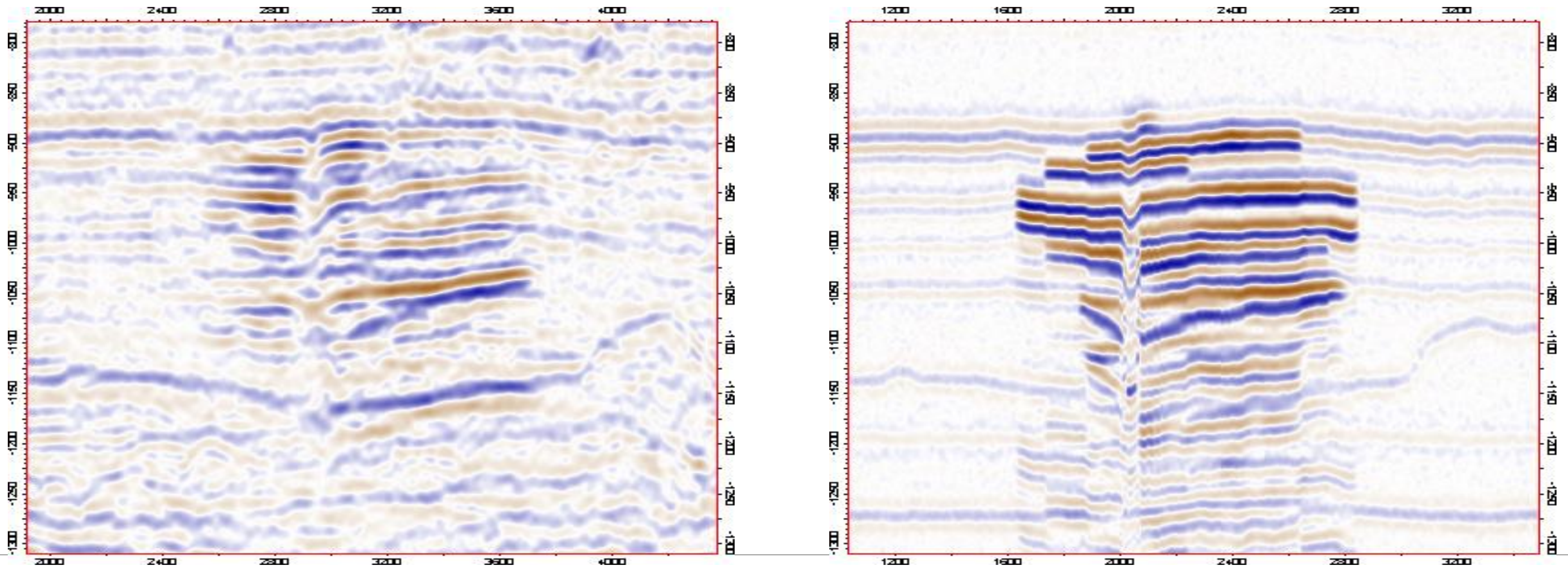


Downhole monitoring

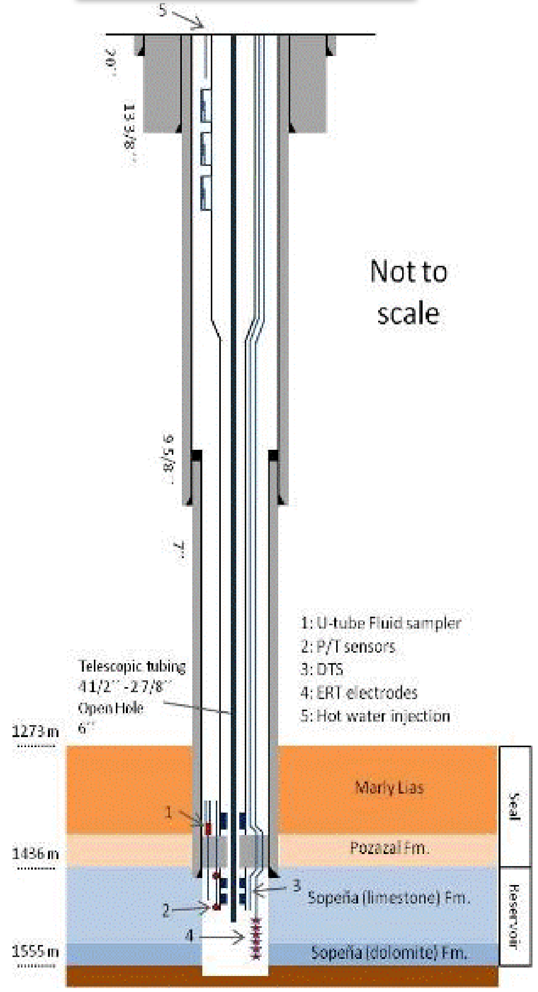
HI Injection Well

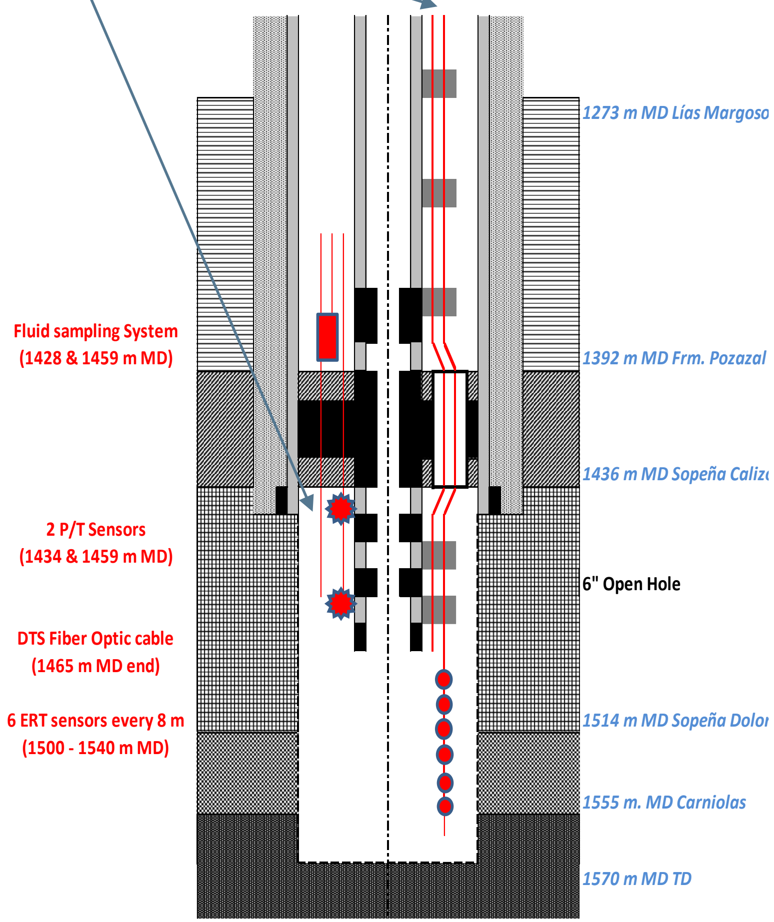
2 P/T sensors located within the reservoir

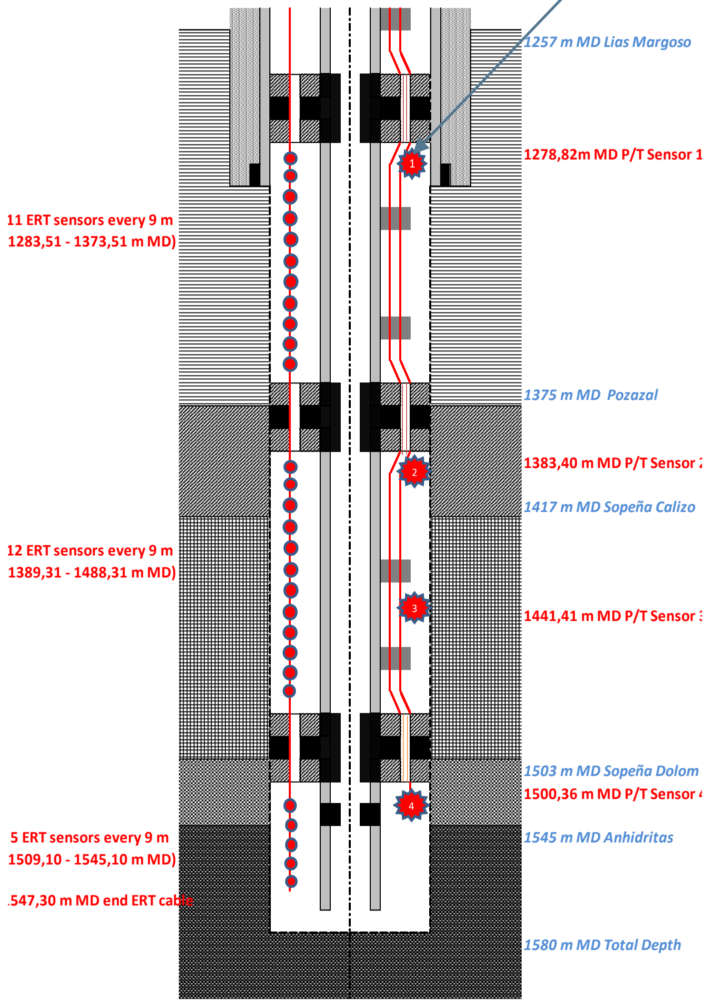
DAS for tubing leakage

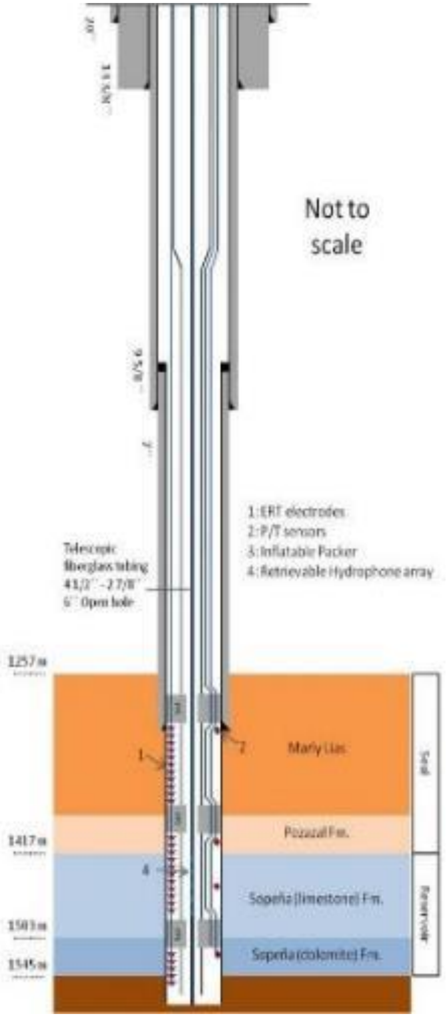
1 P/T sensor located within the cap-rock

HA Observation Well









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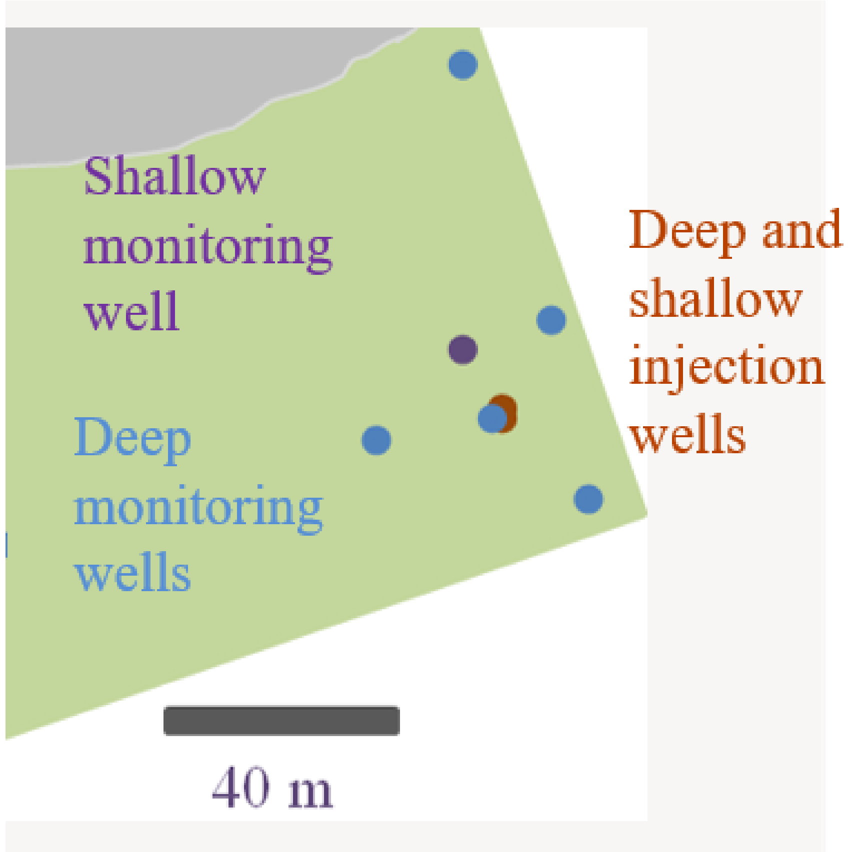
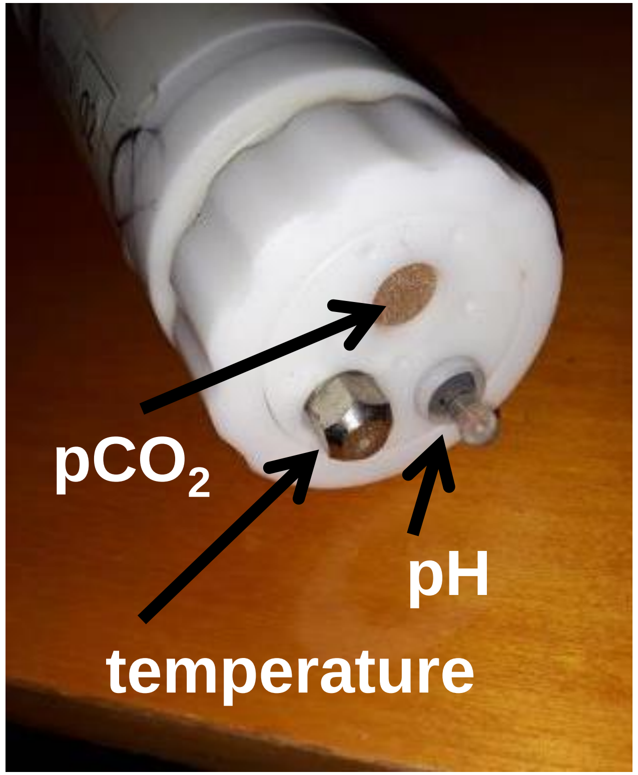
Imaging CO_2 in the subsurface - arrays

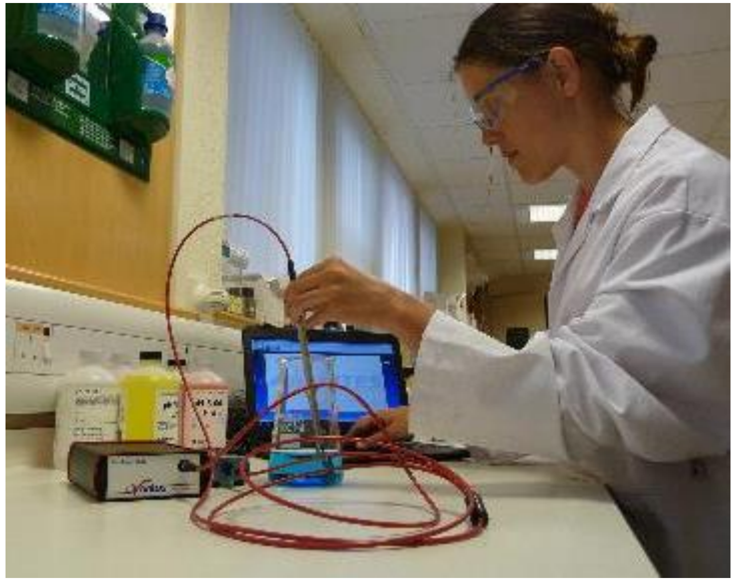
- Electrical Resistivity Tomography (ERT)
- Advanced optic fibre – temperature and acoustic



Groundwater protection

- Direct and indirect (i.e. pH) monitoring of CO_2
- Monitor dissolved & gaseous CO_2 tools - improved sensitivity, reduced cost
- Monitor CO_2 plus other components (multiple sensors that can be used in range of scenarios)





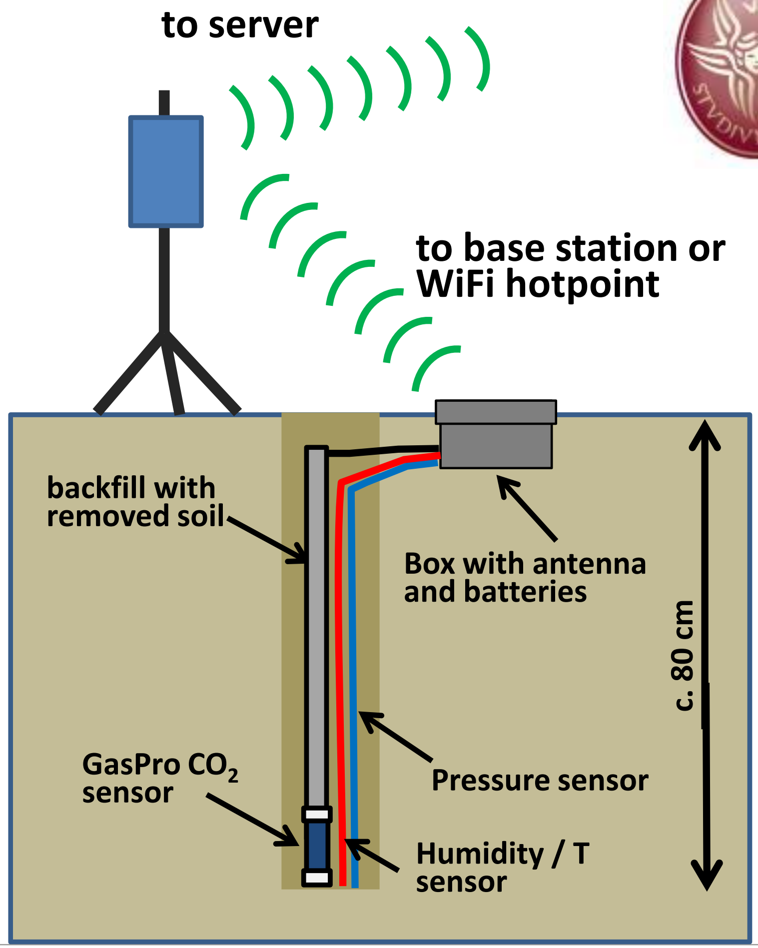
Locating leakage

- Sensitive techniques with rapid response
- Lightweight, compact, faster surveys (mounted on mobile ground vehicle or UAV – CO_2 and CH_4 capabilities, combined sensors e.g. CO_2 plus temperature, airborne hyperspectral thermal imaging technology etc)

Effective soil gas monitoring

- Mass deployments of cheap sensors – network of sensors with remote data access
- Building a more complete picture of the shallow subsurface with advanced soil gas probes (CO_2, soil moisture etc)

BGR



Advanced sampling techniques

- Bio-sensor – using microbiological community as an early indicator of leaking CO_2
- Isotopologues – confirming the source of CO_2

TNO innovation for life

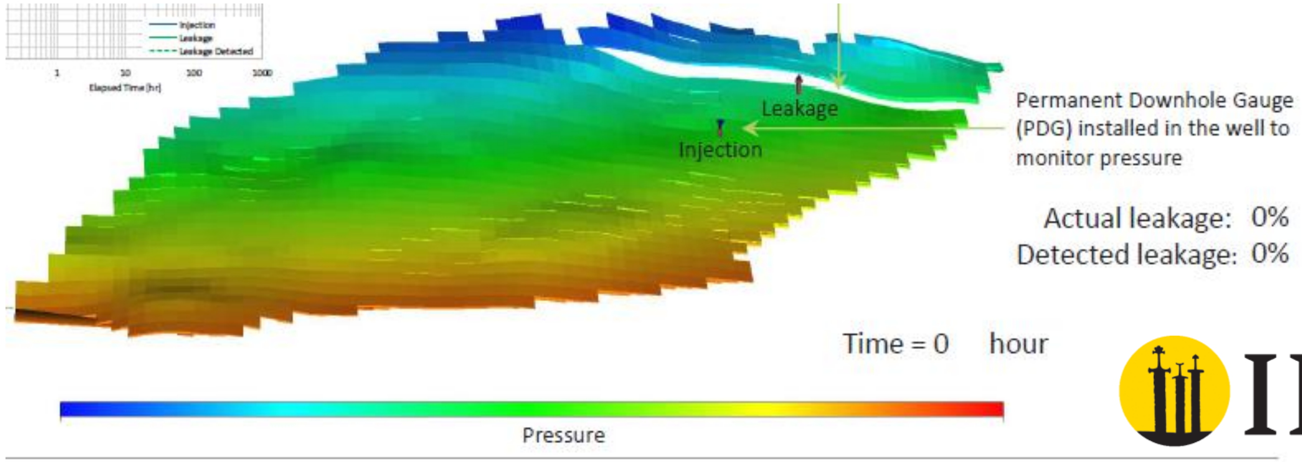
Quantification of leakage

Examining air just above the ground above the CO_2 storage site

- Laser at CO_2 absorption frequency plus array of reflectors (CO_2 and CH_4 capability)
- Analytical technique using point concentration values from CO_2 sensor to estimate total CO_2 flux

Efficient data analysis, processing and interpretation

- Integrated approach to monitoring storage sites is essential
- Streamlined processes are needed (monitoring, data collation, processing and interpretation, modelling….)
- Automated alert system (ENOS, Hontomin)



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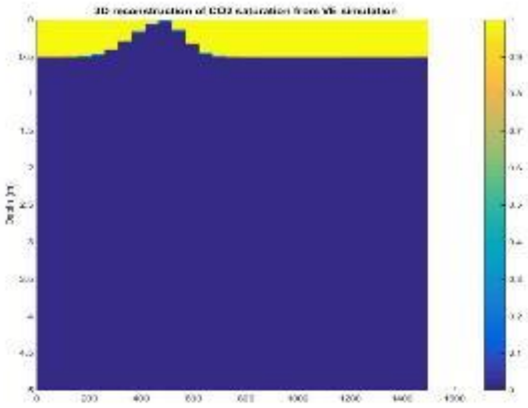

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Verifying new tools & techniques

- New monitoring technologies require verification at field laboratories and/or sites where CO_2 is naturally seeping to the surface
- ENOS sites:
  - Sulcis Fault Lab, Italy
  - Natural seepage sites, Italy
  - UK GeoEnergy Test Bed
  - LBr-1 Czech Republic
  - Hontomin, Spain
  - K12-B
- Also enables fine-tuning of deployment strategies

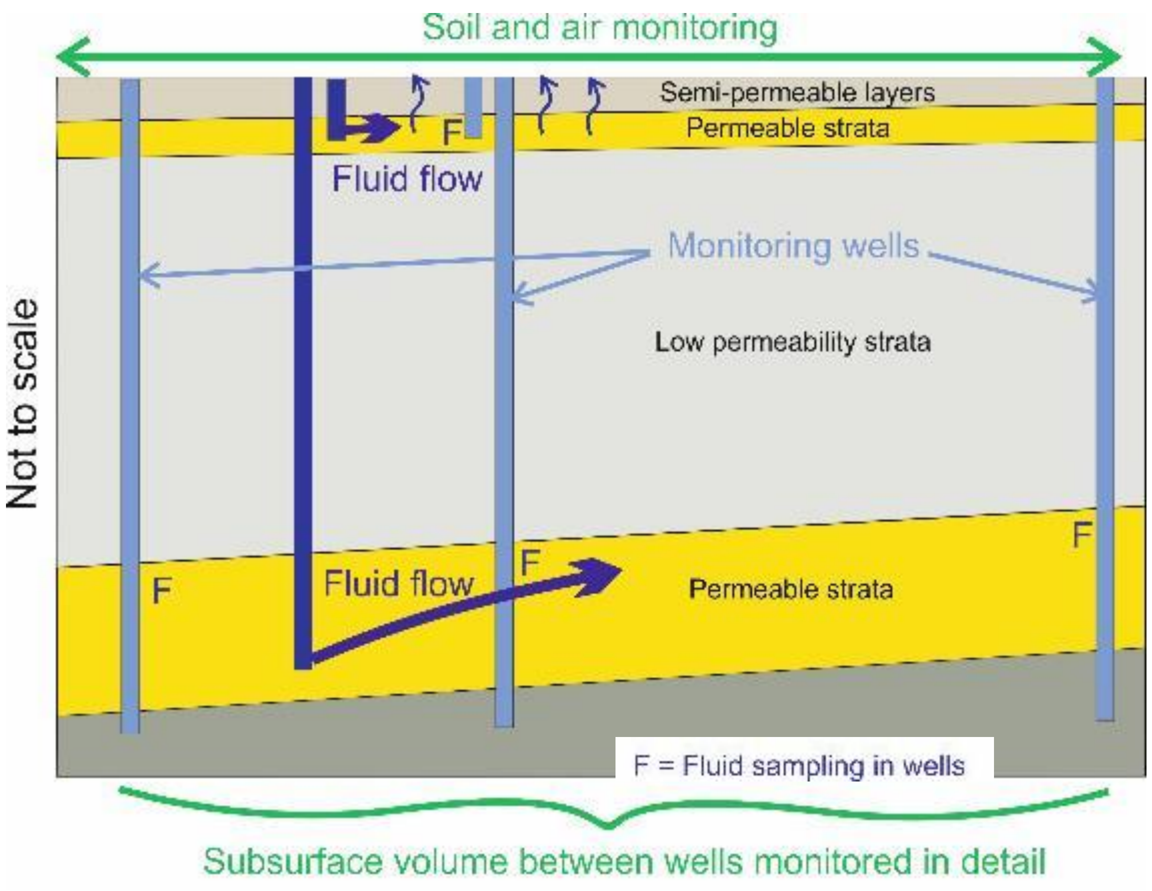

Image: GTB concept

ENERGY RESEARCH ACCELERATOR

ENOS

Thanks to ENOS partners plus Andy Chadwick & Jim White, BGS

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Please come and visit BGS (stand G07) at All Energy 2018

ENOS

Thank you for your time

Project structure

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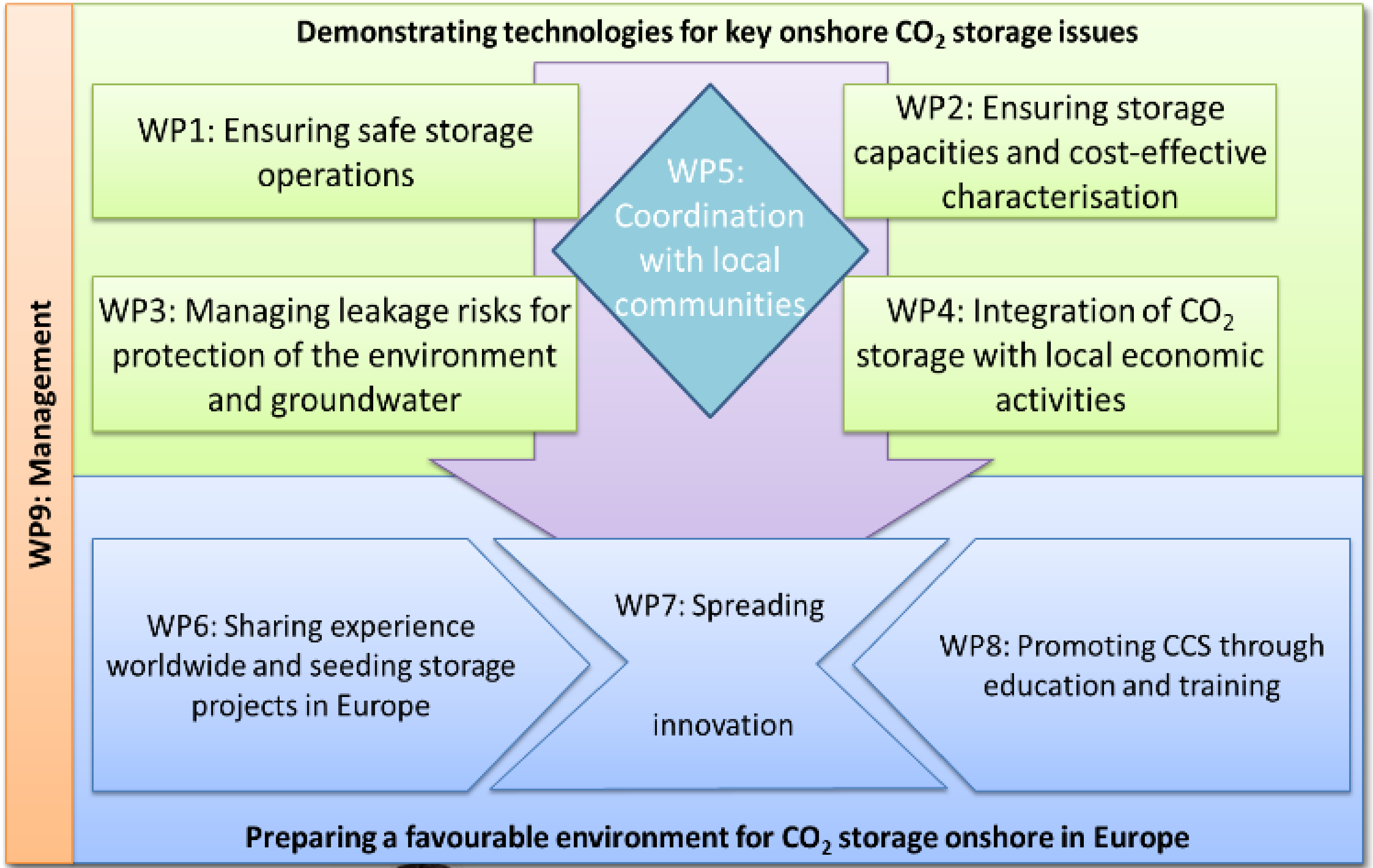
WP1 leader

Ceri Vincent, BGS
WP3 leader



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Ton Wildenborg, TNO
WP4 leader

Vit Hladik, CGS
WP6 leader

Roman Berenblyum, IRIS
WP7 leader

Niels Poulsen, GEUS
WP8 leader

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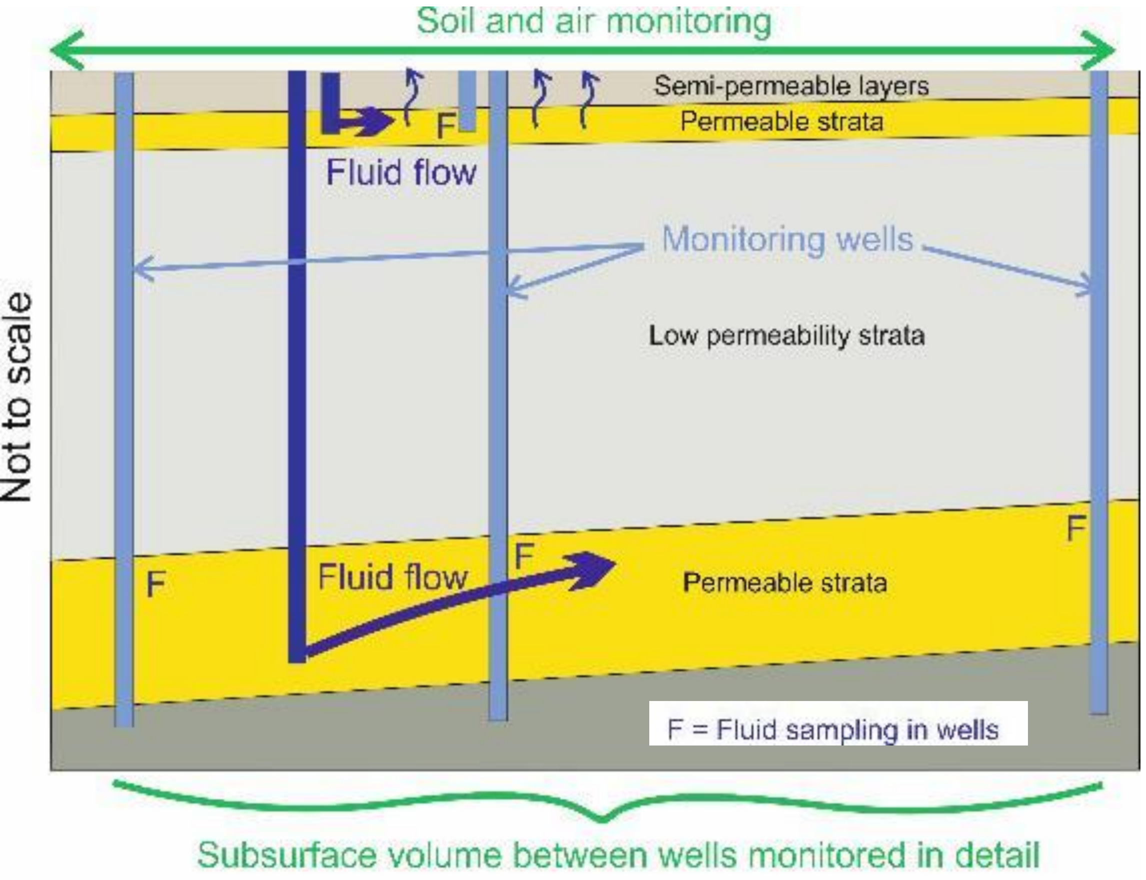
The UK GeoEnergy Test Bed (GTB)

The GTB is a **research facility** initiated by the British Geological Survey and the University of Nottingham comprising an instrumented borehole array



The GTB will:

- **Provide a national facility & catalyse collaboration** between researchers, technology developers and industrial operators
- **Improve understanding** of impacts and processes in the shallow subsurface
- Enable development and testing of **innovative monitoring technologies**
- **Provide ground truthing** for advanced simulation software

For **ENOS**, the GTB will be used to **advance innovative monitoring** technologies and techniques for **detection of fluid migration** in the shallow subsurface **and leakage**

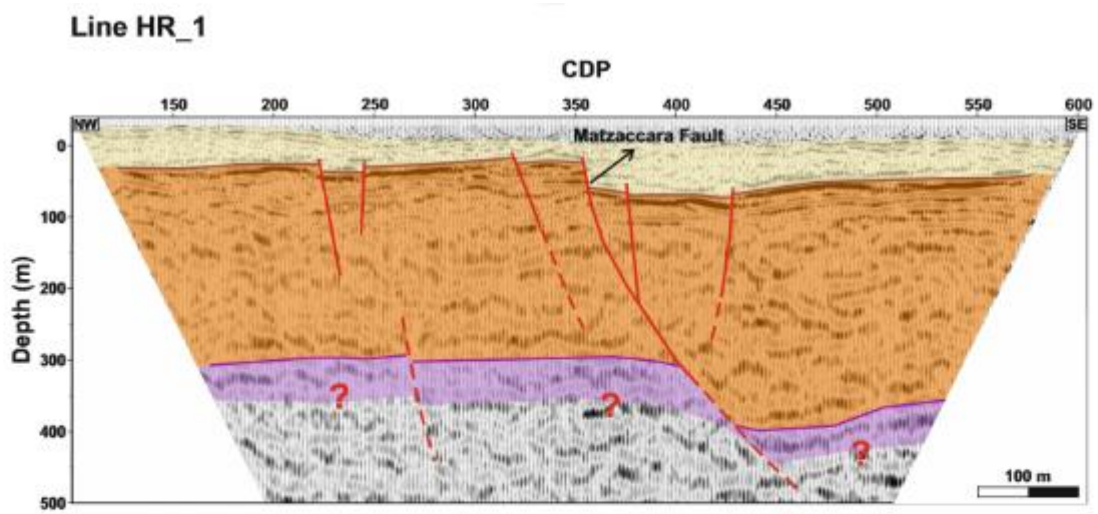
The GTB site represents a £6M investment **to support new and emergent geo-energy sectors critical for a sustainable energy future** (including £2.5M UK government-funding through the ERA project)

Field laboratories – Sulcis Fault Lab (SFL)

CO_2 will be injected into a fault zone (depth c. 250-300 m) to better understand impacts of CO_2 leakage.

SFL will test the sensitivity and effectiveness of monitoring techonologies and techniques designed and developed by ENOS partners.

SFL infrastructure is **funded by Sardinian Region and National funds** – (Center of Excellence for Clean Energy and Research on Electric System)



The SFL project has multiple purposes:

- Study CO_2 **migration through faults**;
- Examine water-gas-rock interactions including potential changes of **groundwater quality**;
- **Study behaviour & changes in rock / fault parameters** by monitoring micro-seismicity and technical rock characteristics;
- **Test geochemical and geophysical monitoring tools** (in-house manufactured and low cost CO_2 sensors)
- Develop a **robust groundwater monitoring strategy**
- Increase **public engagement** and build dialogue with citizens

LBr-1, Czech Republic

Depleted hydrocarbon field in the Czech part of the Vienna Basin, produced mainly in the 1960s

Tertiary **sandstones** at ca. 1100 m depth

Planned **ENOS** WP3 activities:

- **Assessment of leakage risks** through abandoned wells and faults, including possible shallow groundwater contamination

Fieldwork at sites with natural CO_2 seeps

- Will use a number of natural sites where CO_2 is leaking at the surface to study migration styles, especially along faults. ENOS sites include:
    - Ailano, Latera, San Vittorino Italy
    - Leakage mechanisms: Faults and fracture zones
- ENOS testing rapid survey systems, controls on leakage and is low-level diffuse leakage important? Source attribution methods and quantification tools

WP3 Managing leakage risks for protection of the environment and groundwater

Advance and validate surface and downhole monitoring technologies relevant to onshore storage, including for groundwater protection

Improve understanding on the impacts of leakage and of potential leakage pathways (geological faults and boreholes) to enable a more effective monitoring strategy

Produce best-practice guidelines for a monitoring programme that integrates the newly advanced ENOS technologies and techniques with state-of-the-art commercially available tools

Real-life experience from field laboratories and sites where CO_2 is naturally seeping to the surface used to realise these aims (and data made available for future research)

Sites involved:

- Sulcis Fault Lab, Italy
- LBr-1, Czech Republic
- UK GeoEnergy Test Bed

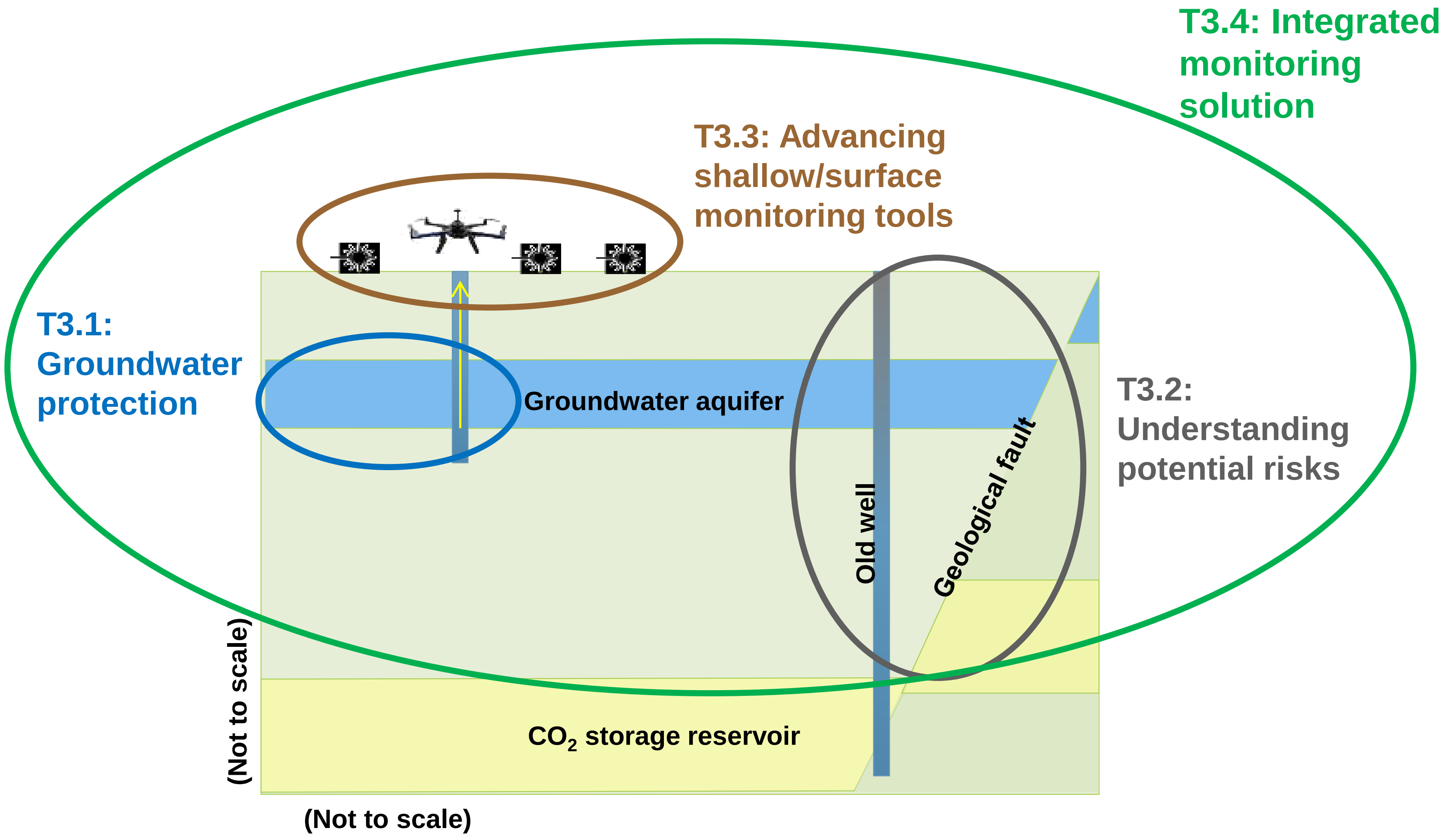
ENOS WP3 – monitoring for protection of the environnent and groundwater

T3.1 Groundwater protection: Demonstrate the efficacy and to advance techniques and technologies suitable for use in drinking water aquifers

T3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring

Task 3.3: Development of surface monitoring tools towards quantification of CO_2 leakage

Task 3.4: Integrated monitoring solution for leakage detection and quantification:



Groundwater protection – T3.1

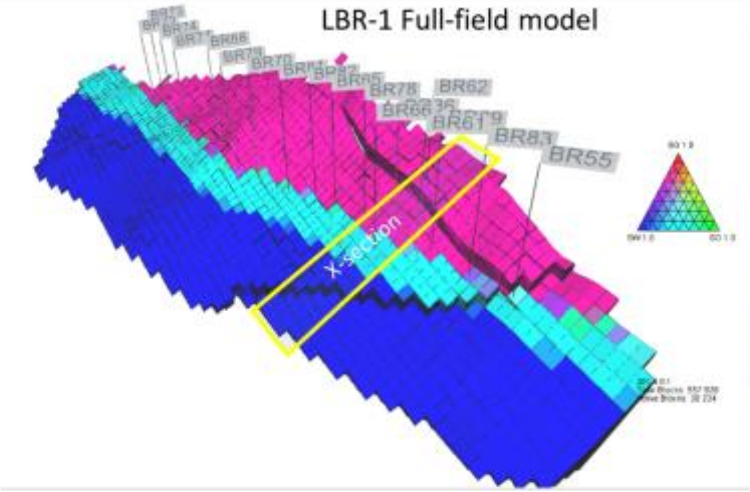
Objectives/Impact: Effective monitoring strategies to locate leakage will be developed, the most sensitive parameters highlighted, sensitivity of tools improved and low cost solutions capable of long term deployment developed

Tasks:

- **Tool box** based on water-gas-rock interaction
- **Advance 5 tools;** sensitivity and cost optimised **for monitoring potable aquifers**

Testing one of the downhole tools

Assessing risk presented by faults & boreholes – T3.2



Objectives/Impact:

- **Improved understanding of the risk posed by faults**
- **Improved monitoring strategies** based on new understanding
- Data to feed technical guidelines on **mitigation of risks through intelligent site design and monitoring strategies** based on risk assessment of boreholes and faults

Tasks:

- Assess **what makes a fault more likely to leak**, model leakage pathways
- **Assess effectiveness of geophysical techniques for monitoring of CO_2 migration** through fault planes (surface and subsurface)
- Examine **expression of leakage** through faults at surface for more efficient monitoring
- Modelling and assessment of **leakage risk presented by old boreholes**; produce technical guidelines/best practice for case study

Development of surface/near surface monitoring tools - T3.3

Objectives/Impact: Advance tools/techniques for CO_2 leakage identification, assessment and quantification (in the unlikely event leakage were to occur). Technologies applicable to onshore storage will be taken to at least TRL6 through field demonstration

Ground CO_2 mapper field test

Tasks:

- **Wide areal detection tools** for effective leakage identification (3 tools)
- **Advanced (soil) gas monitoring tools** to confirm CO_2 concentration and source (2 tools/techniques)
- **Quantification** of leakage (2 tools)