… INTEGRATED BOREHOLE SURVEY DESIGN FOR DETECTION OF MIGRATING CO2 ON FAULT PLANES AT SULCIS FAULT LAB

Flavio Poletto (OGS)

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WORKSHOP II - Post-Open Forum workshop organised by ENOS
Venice, 26 April 2018, 14:00 – 17:00
"Storage site solutions: monitoring and verification"

Key aspects and outline

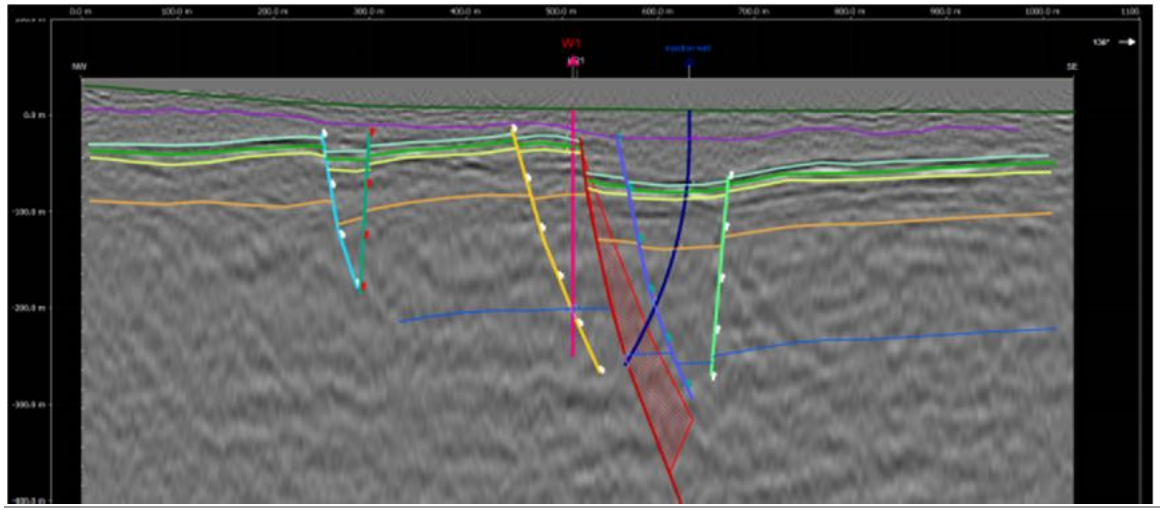
- Monitoring CO2 migration through fault planes in the SFL sub-surface (**WP3 Task 3.2.2**), Integrated downhole survey design

- Initial (actual) information (no wells)
- Geophysical characterization
- Well plan and instrumentation design
- Sensitivity (instrumental response)
- Injection plan and sensitivity to CO2 (geophysical monitoring)

Integrated downhole survey design

➢Initial (actual) information from **surface** (no wells)

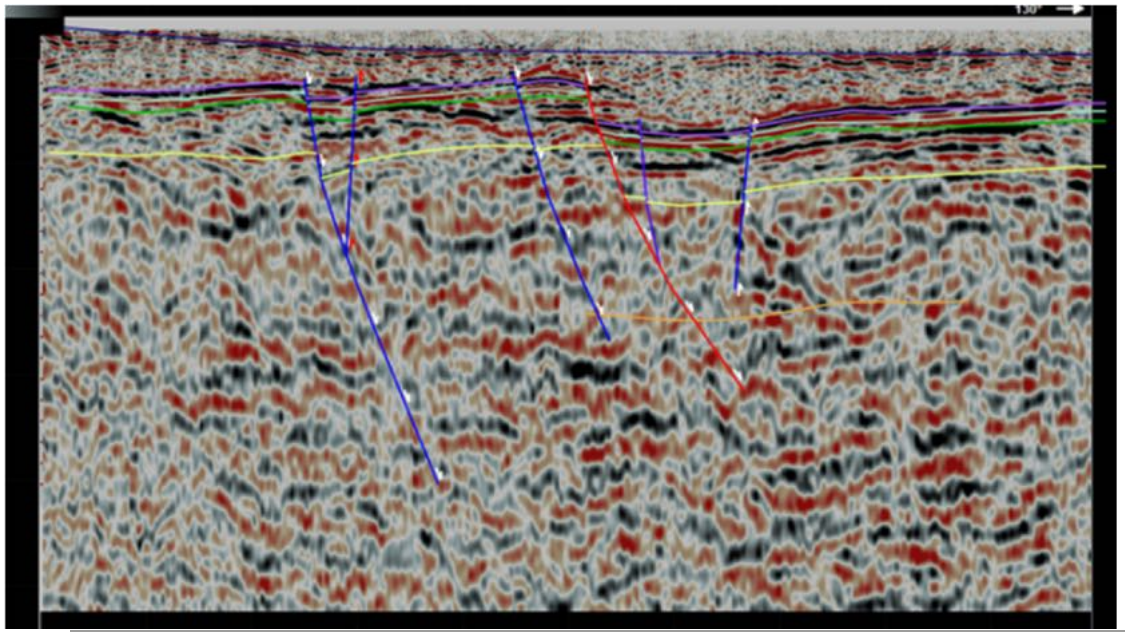
- High resolution surface seismic lines (HR1 and HR2) (Sotacarbo, processed by OGS)
- Electrical Resistivity (ERT) data (Sotacarbo)
- Geological data and fault's interpretation (UniRoma1 Sapienza)

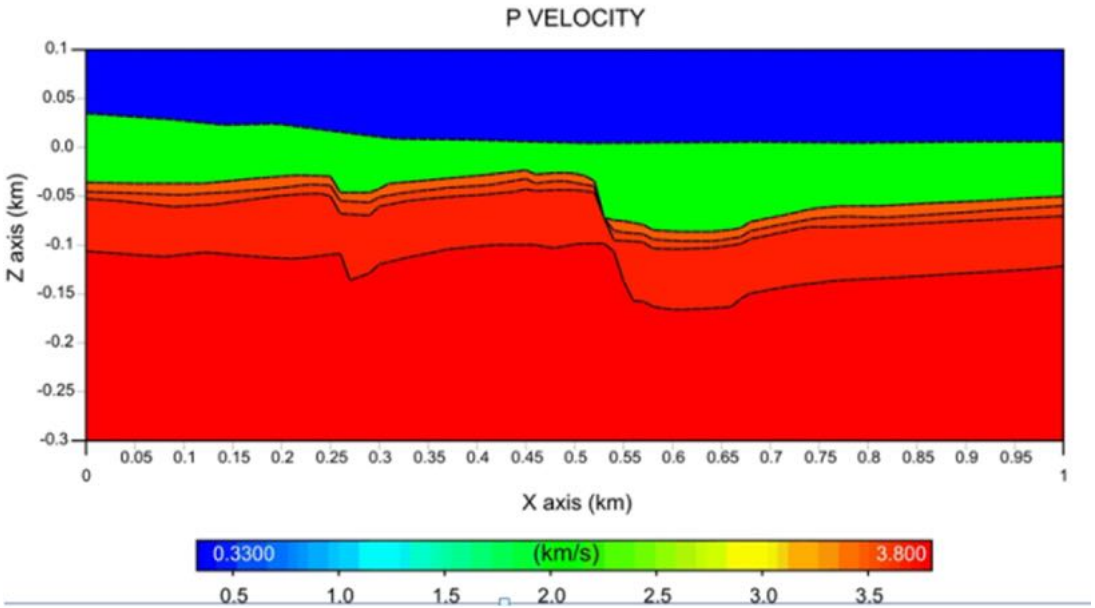


Interpretation on HR1 line

Geophysical characterization

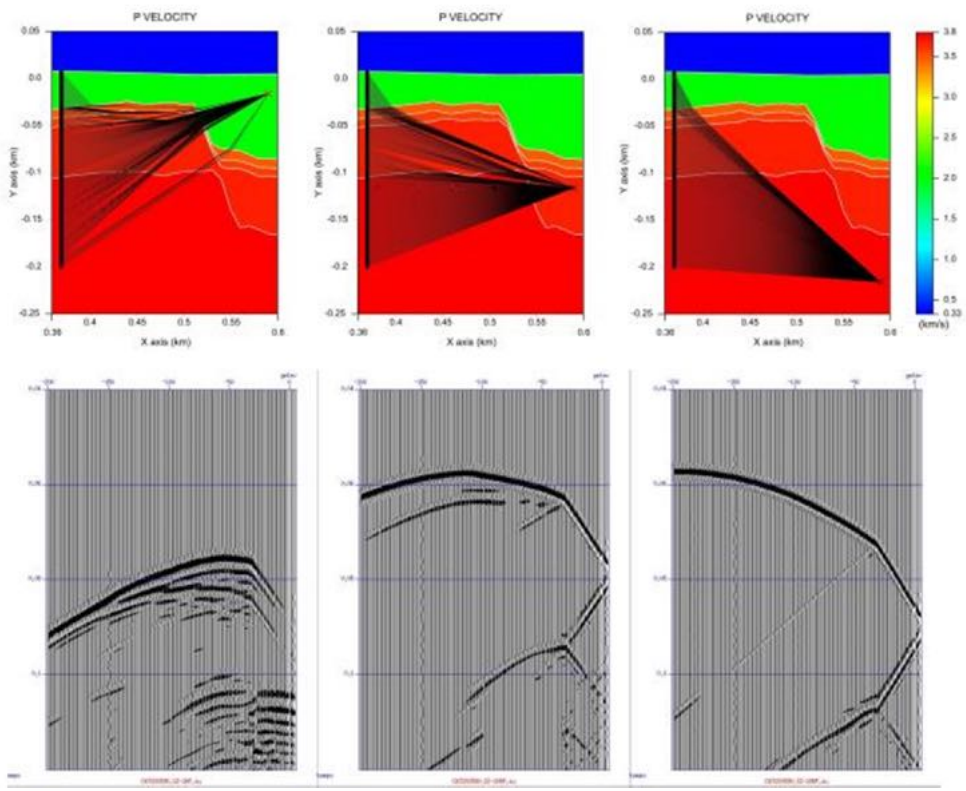
- Two wells (monitoring vertical W1, injection directional WI)
- Borehole measurements

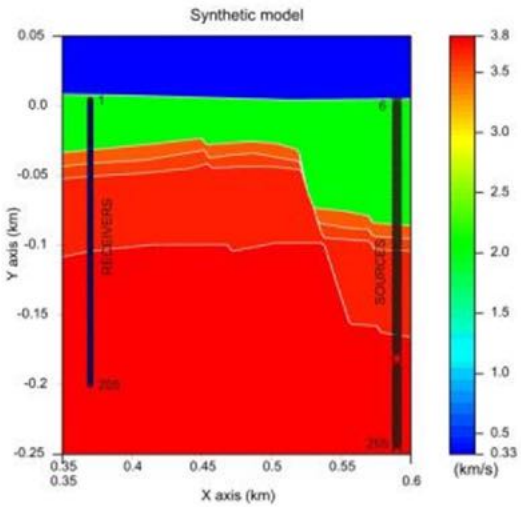




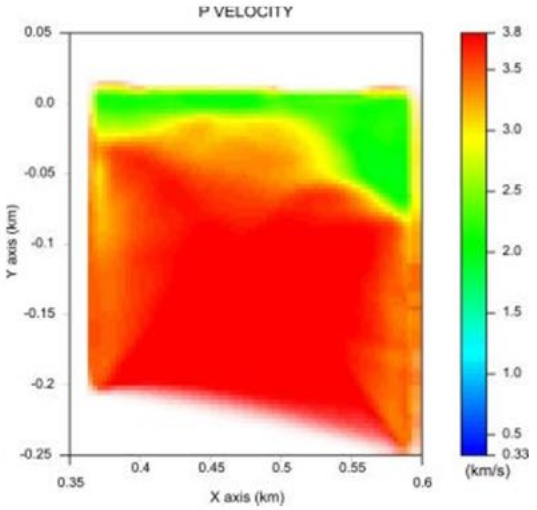
Geophysical characterization (from surface seismics)

- Cross-well (CW) borehole measurements (synthetic simulation)





HR1 model

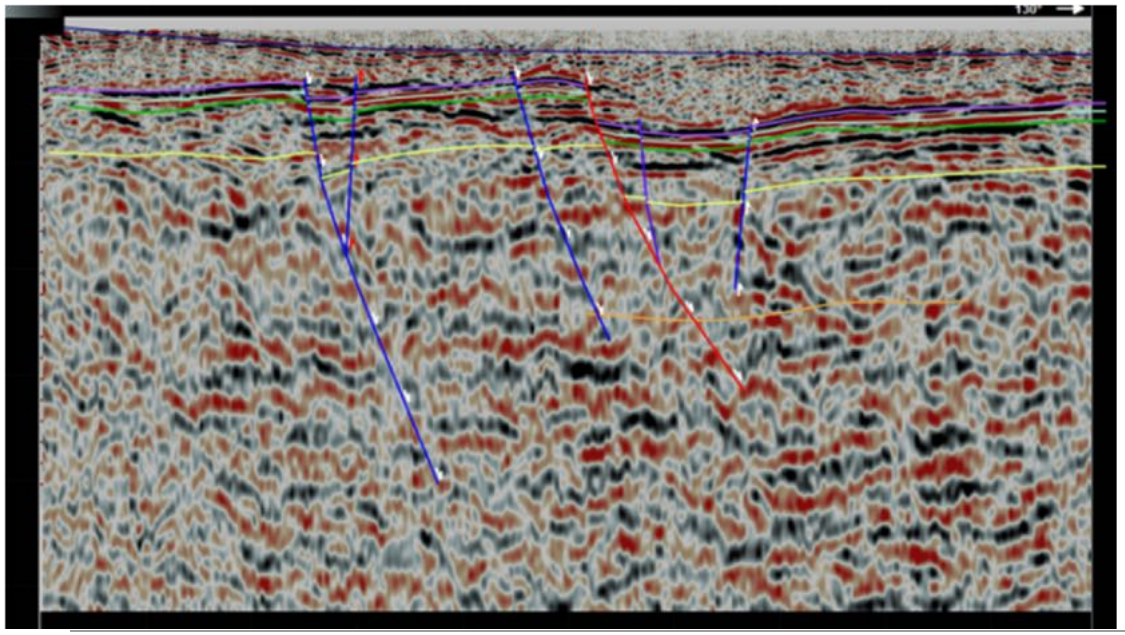


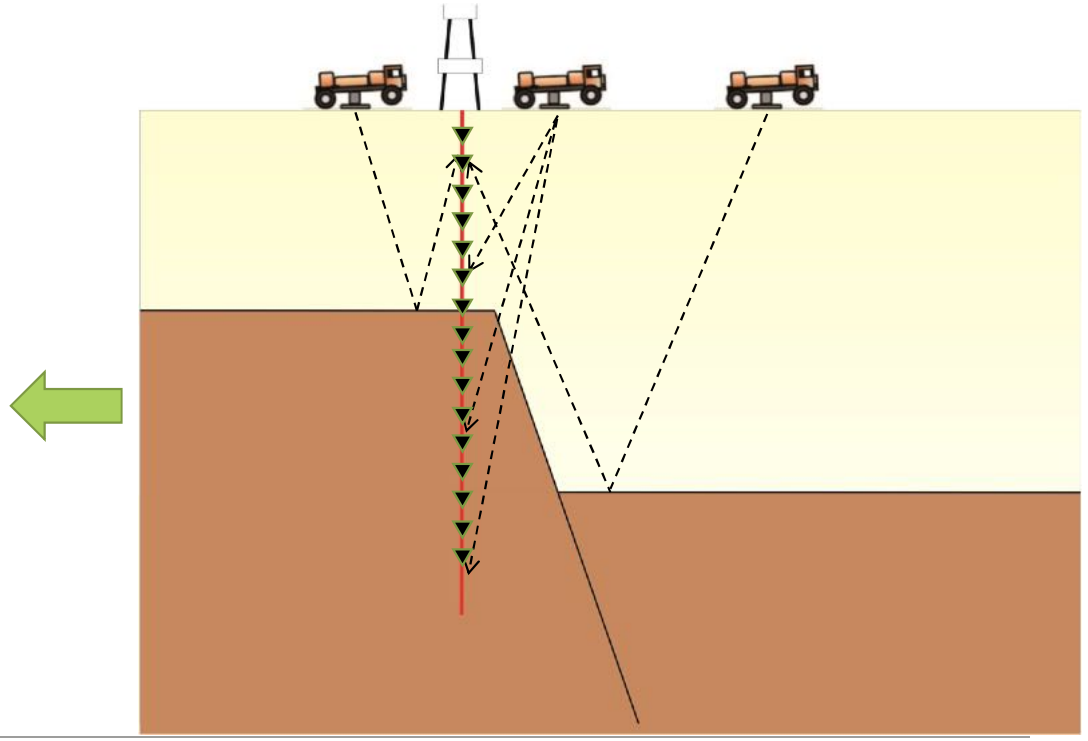
CW tomography (synthetic)

Drill first W1 SFL observation well (vertical ca 300 m)

- Borehole and well measurements (VSP, logs and coring)
- Surface seismic depth-calibration

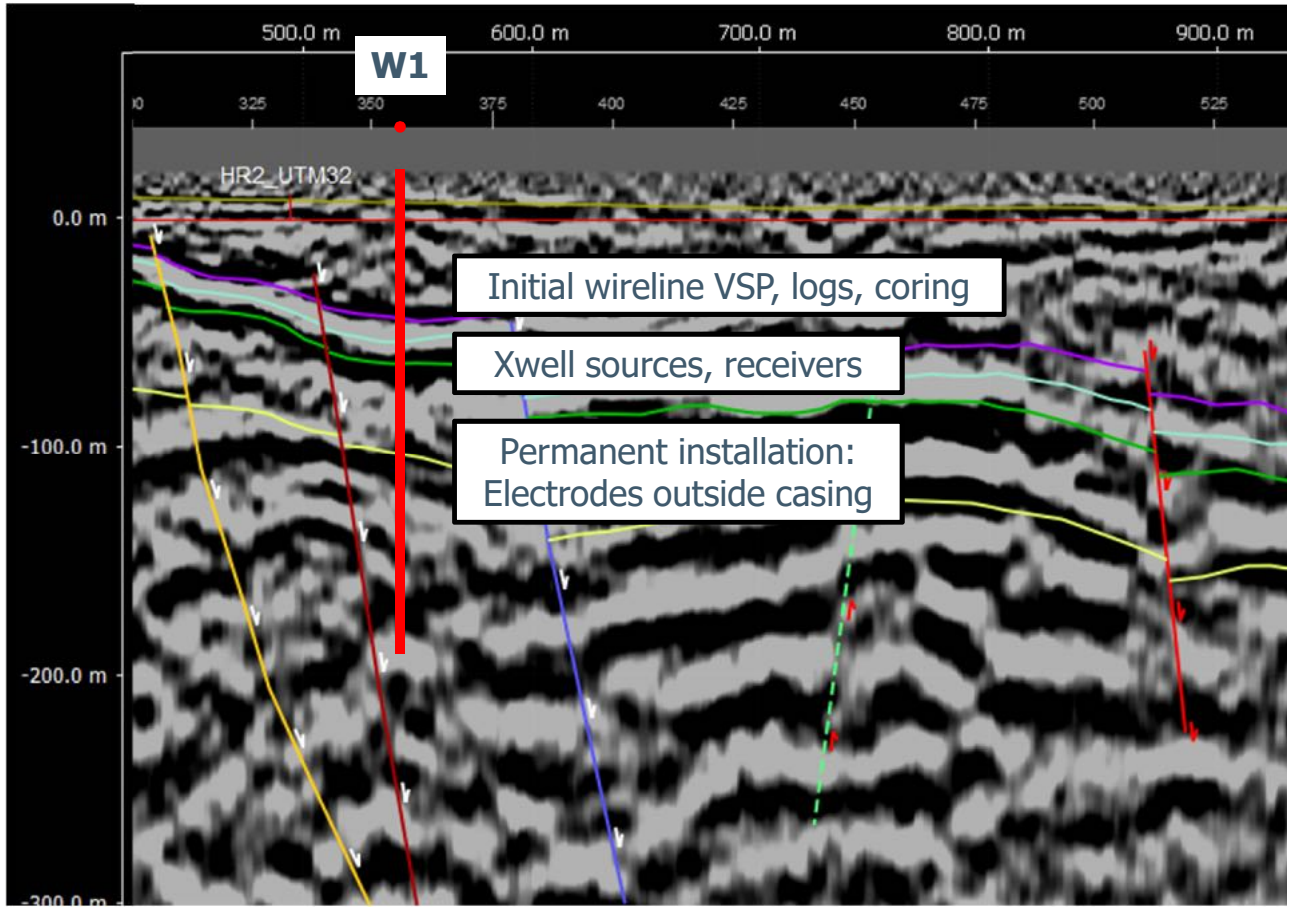
➢ Depth information for injection well





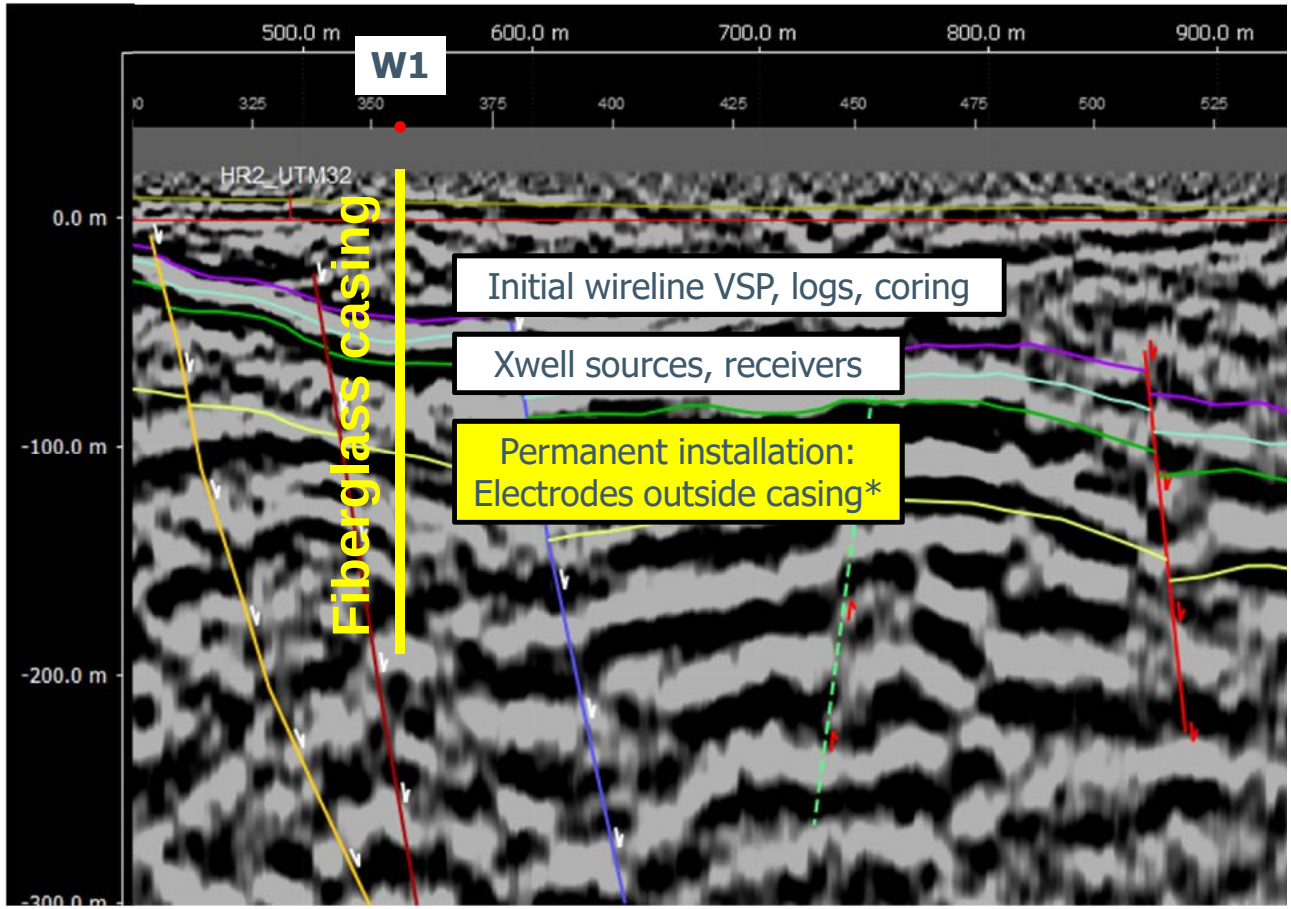
First well (W1) instrumental design scheme

- Sensitivity and response (permanent and wireline instruments) in **W1**



First well (W1) instrumental design scheme

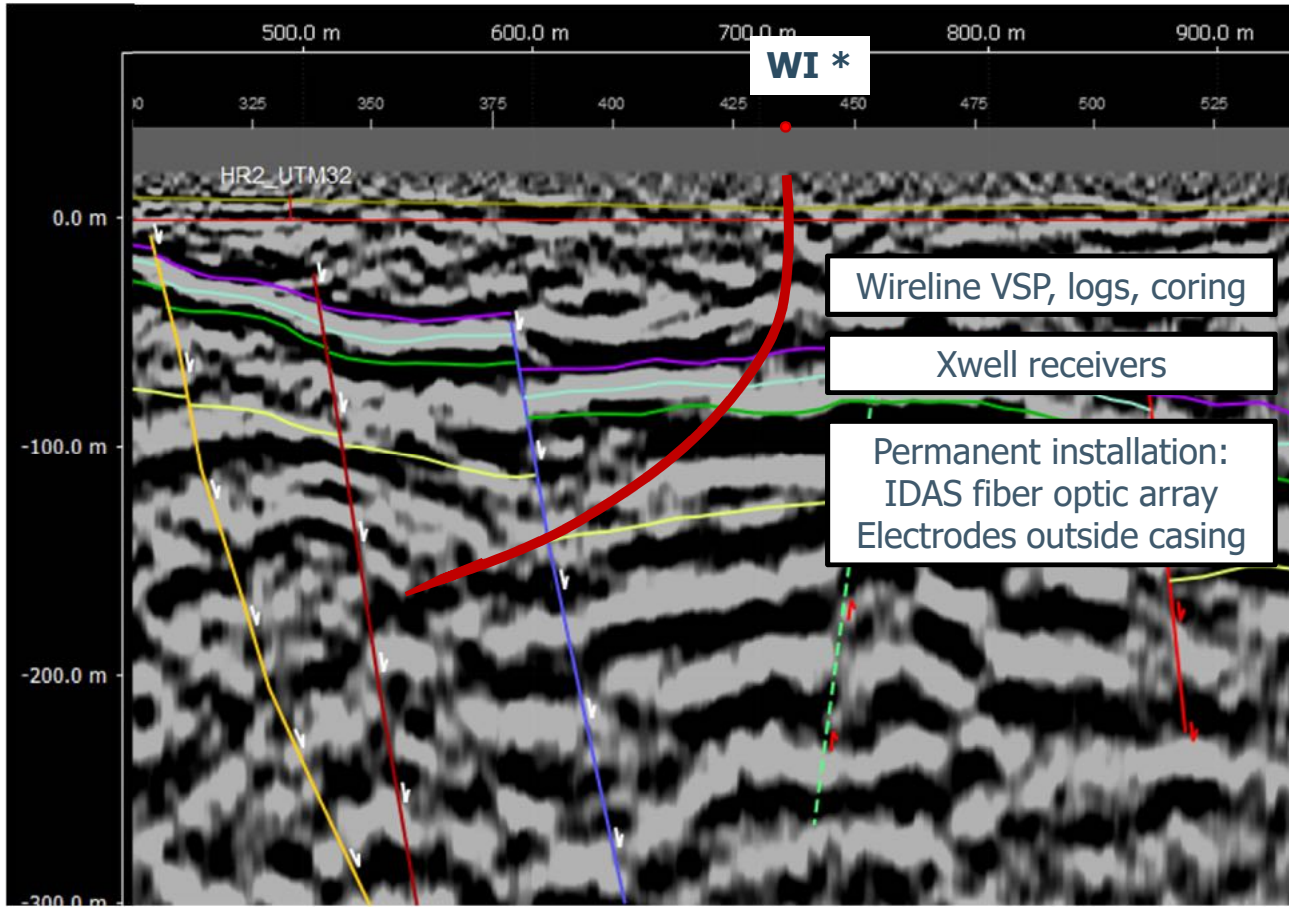
- Sensitivity and response (permanent and wireline instruments) in **W1**



(*) Fiberglass or equivalent

Injection well (WI) instrumental design scheme

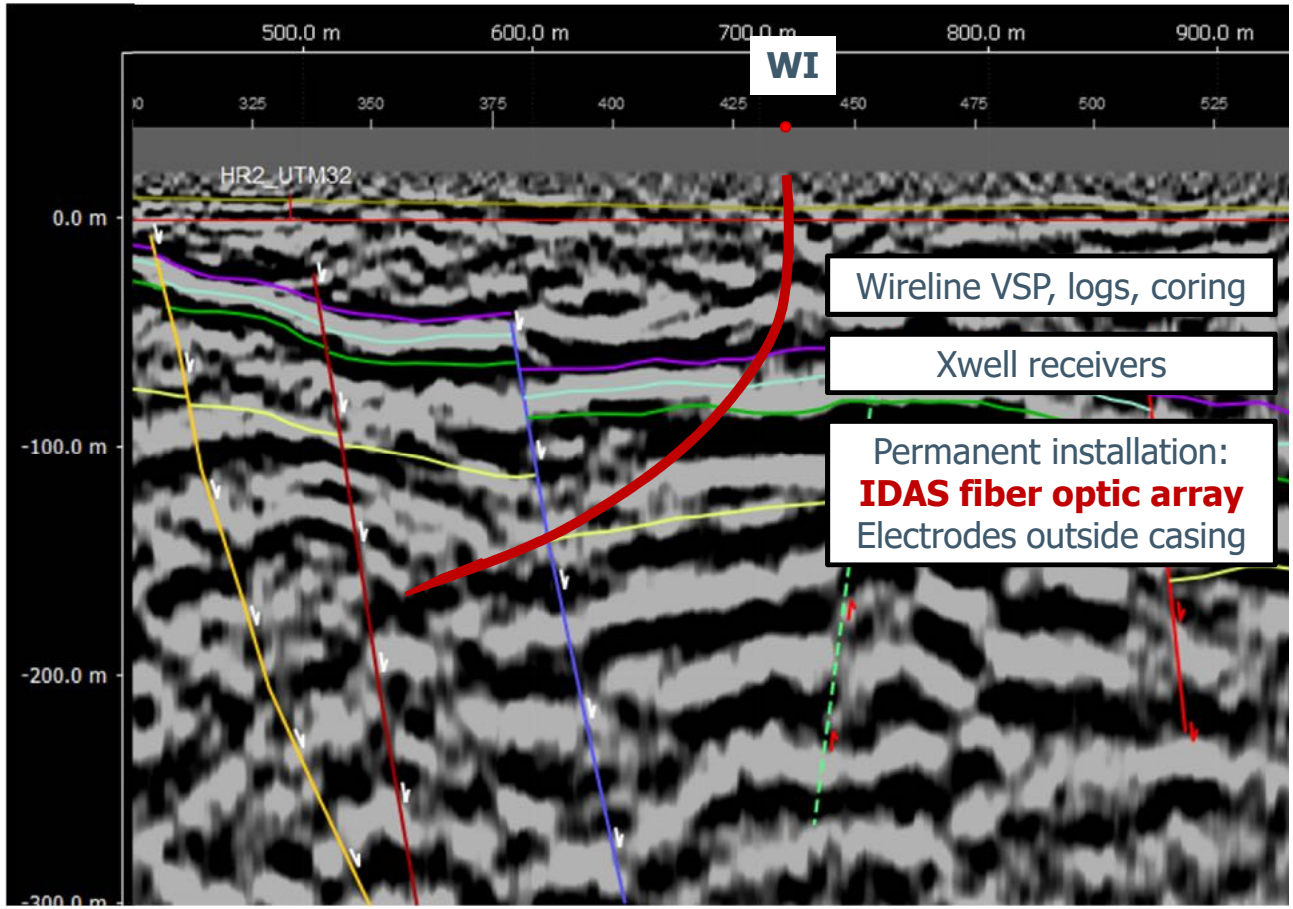
- Sensitivity and response (permanent and wireline instruments) in **WI**



(*) WI measurement scheme shown with initial- indicative directional well geometry

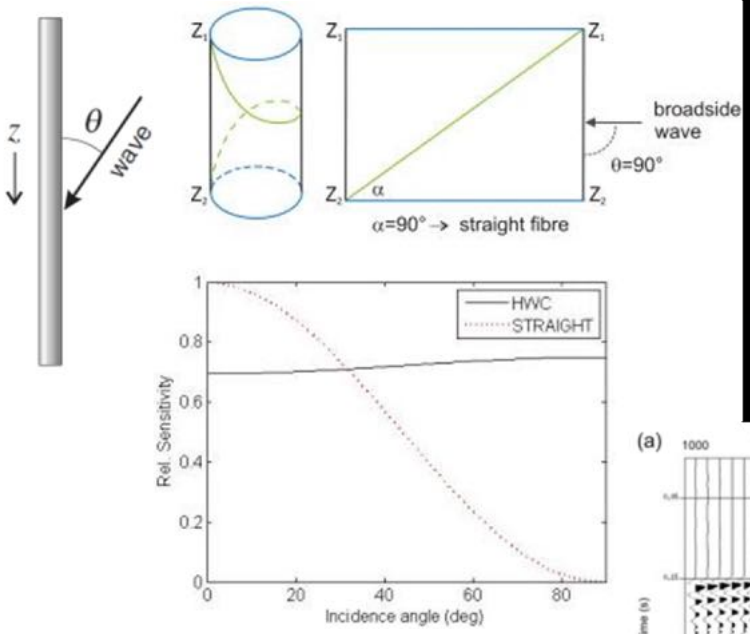
Injection well (WI) instrumental design scheme

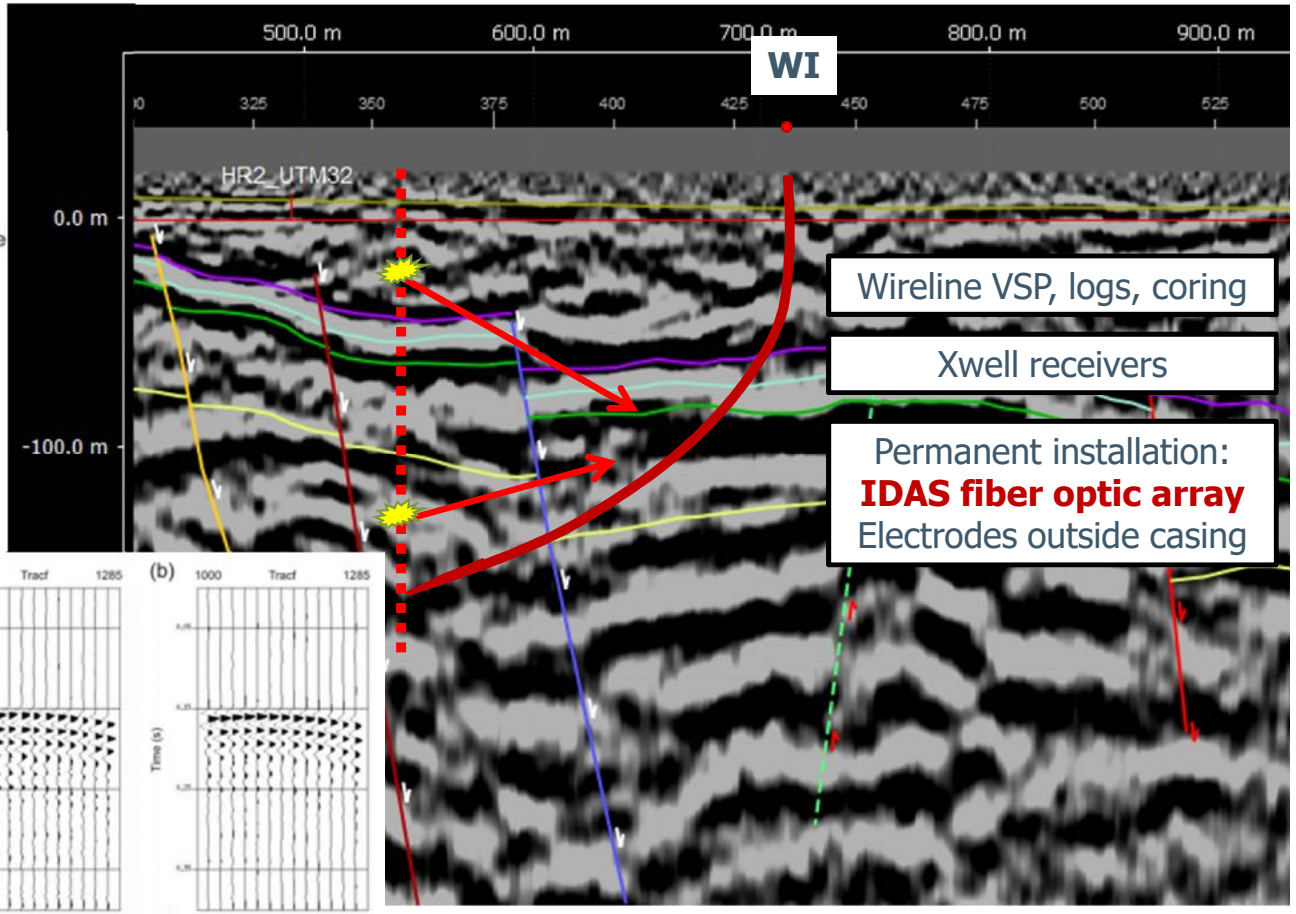
- Sensitivity and response (permanent and wireline instruments) in **WI**



DAS innovative technology: constellation (30 dB), HWC

- Sensitivity and response





Hydrophone and DAS HWC

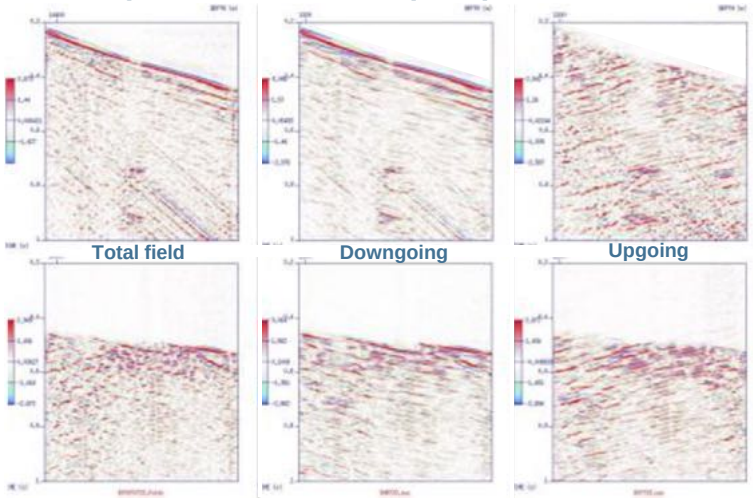
DAS innovative technology: dense space array (dual)

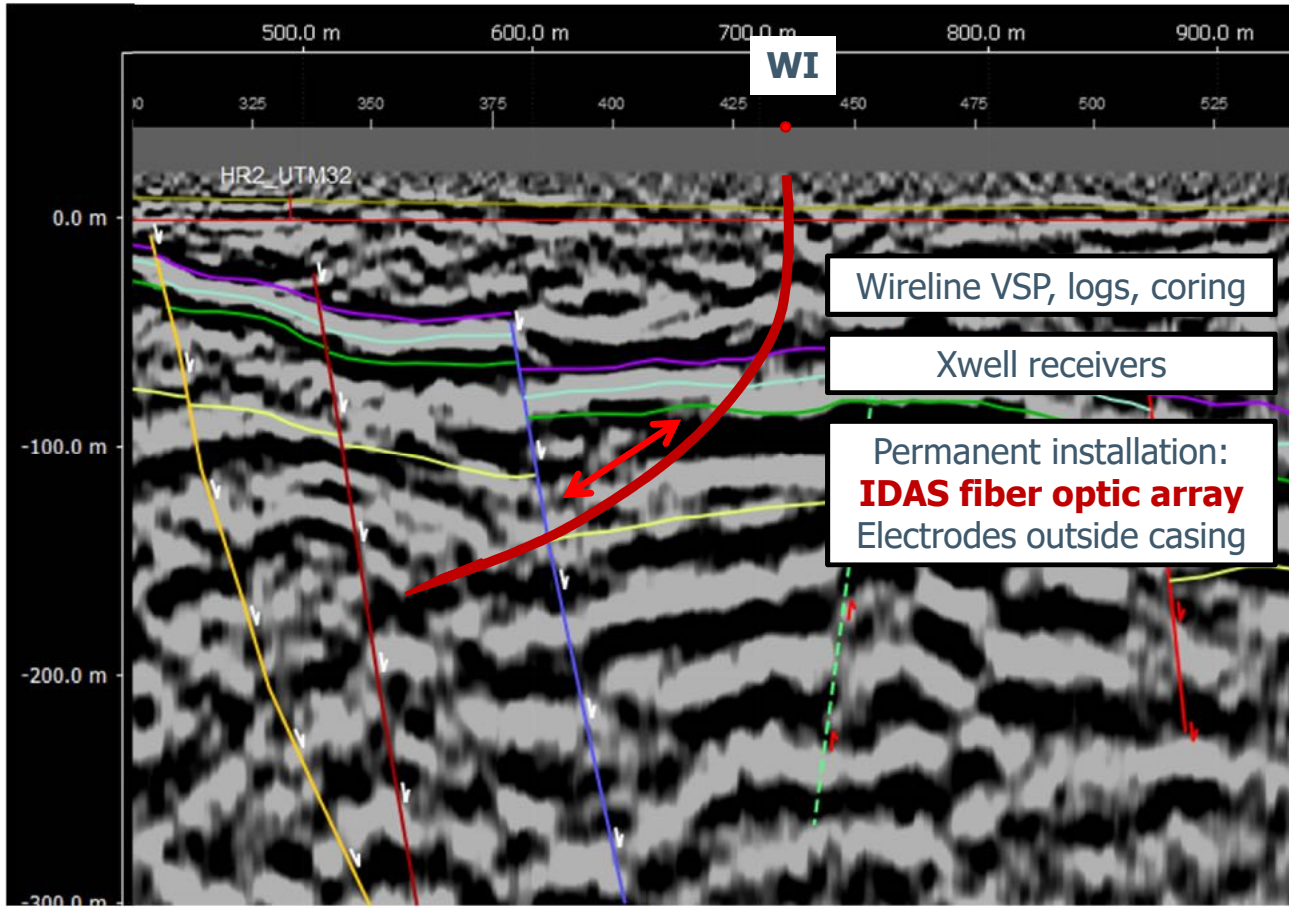
- Dual wavefield separation (Poletto et al, 2016)

$$ikDW\exp[i(\omega t+kz)]=\frac{\varepsilon(z,t)+Fv(z,t)}{2}$$

$$ikUP\exp[i(\omega t-kz)]=\frac{\varepsilon(z,t)-Fv(z,t)}{2}$$

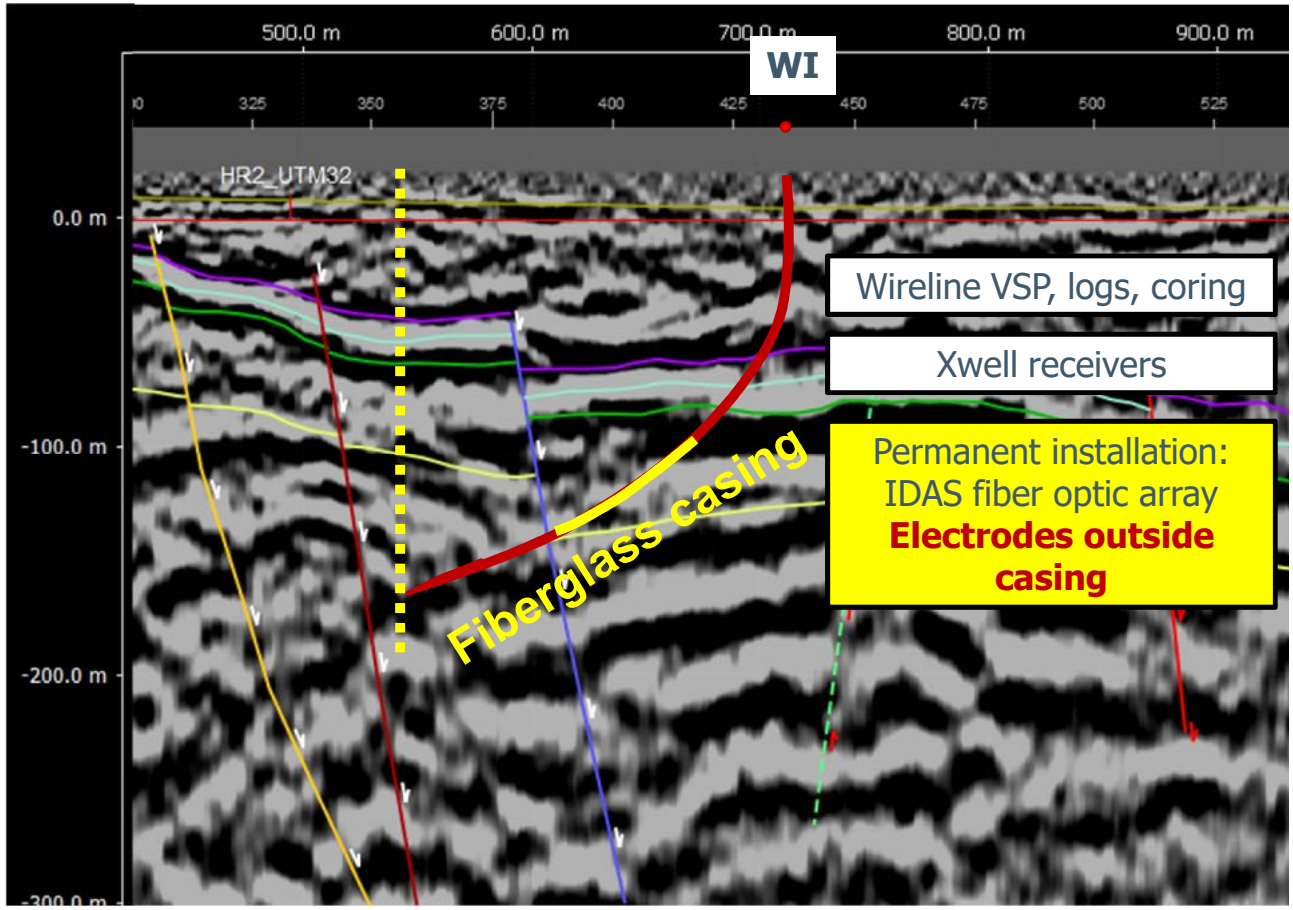
Example from Hontomin (WP1)





Sensitivity (instrumental design)

- CW sensitivity and response (permanent and wireline instruments) in **WI**



Sensitivity (geophysical monitoring)

- Injection plan and sensitivity to CO2 (geophysical monitoring)
- Well plan and instrumentation design **(Well's site HR1)**

- Layouts including wells and injection, after UniRoma1 Sapienza fault's interpretation
- Cross-well seismic simulation
- Geo-electric (ERT) monitoring simulation

Sensitivity (seismic simulation for HR1 wells)

- Injection plan and sensitivity to CO2 (geophysical monitoring)
- Well plan and instrumentation design **(Wells HR1)**

➢ CO2 conditions at P = 30 atm, T = 18 °C:

ρ = 68.178 kg/m3, Vp= 237.88 m/s

Porosity = 9%

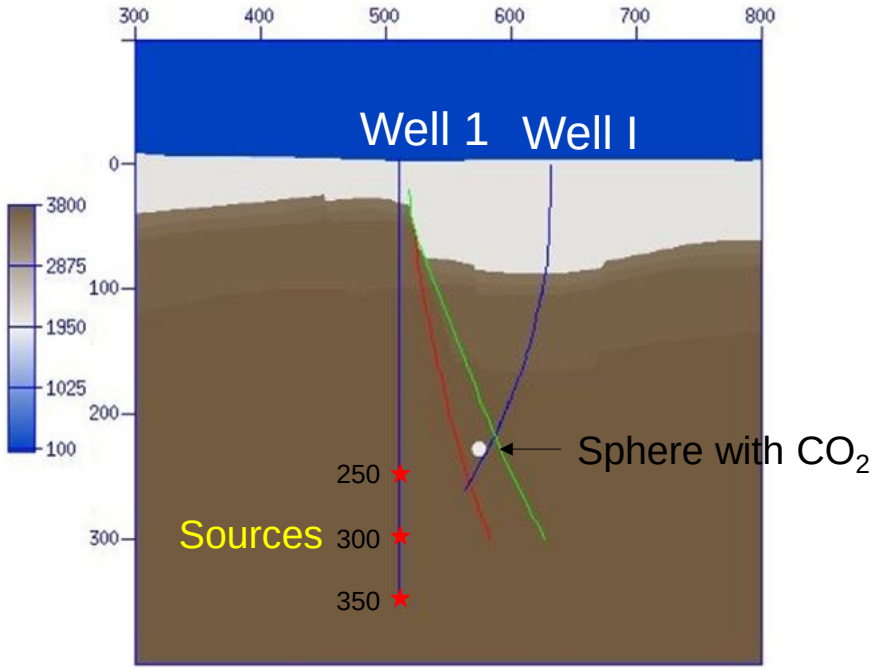
➢ Injected mass: M = 5.5 ton → sphere with R = 6 m

➢ Simulation parameters (2D finite difference):

Source: pressure, Ricker wavelet fc = 400 Hz

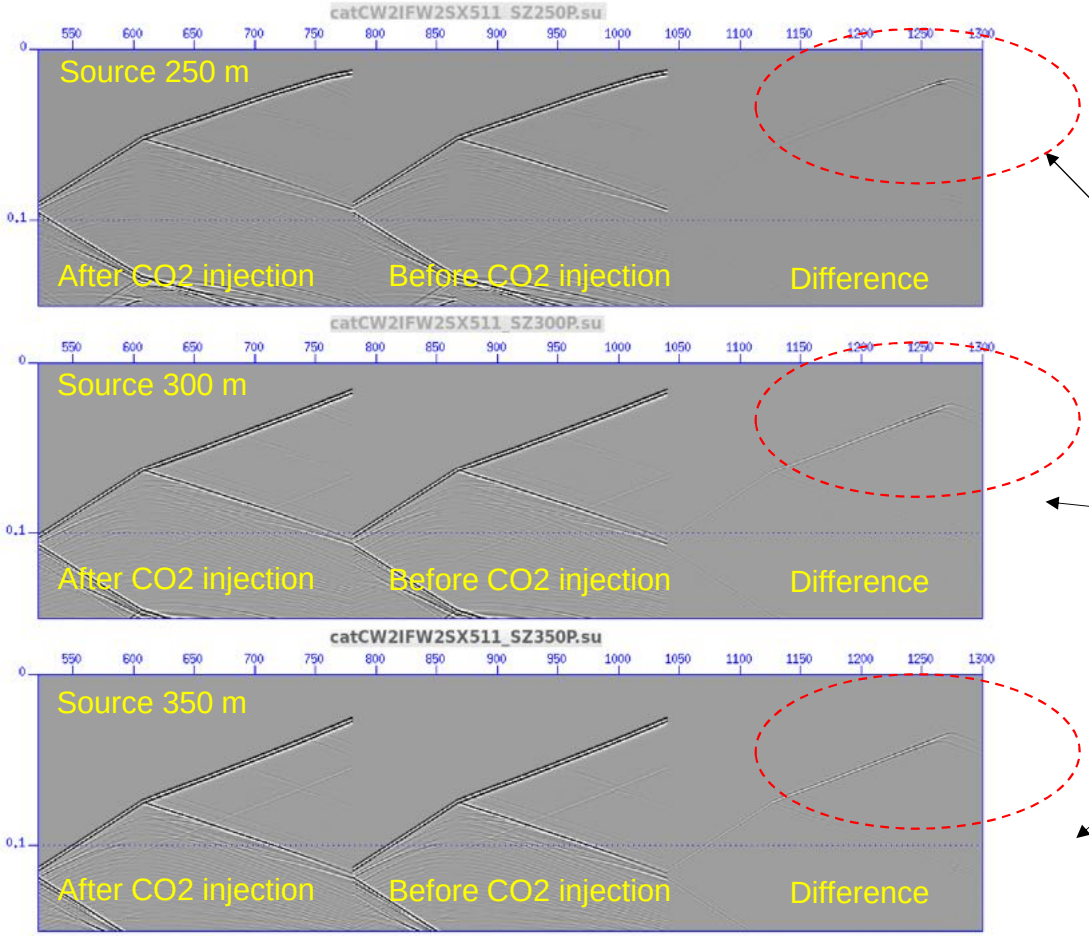
Model discretization: dx = dz = 0.5 m

Acquired component: pressure



Sphere centre at 228 m depth

Sensitivity (seismic simulation for HR1 wells)



Time lapse difference:
with CO_2 sphere - without sphere

Sensitivity (electric response simulation)

- Injection plan and sensitivity to CO2 (ERT geophysical monitoring)
- Well plan and instrumentation design **(Wells in HR1 location)**

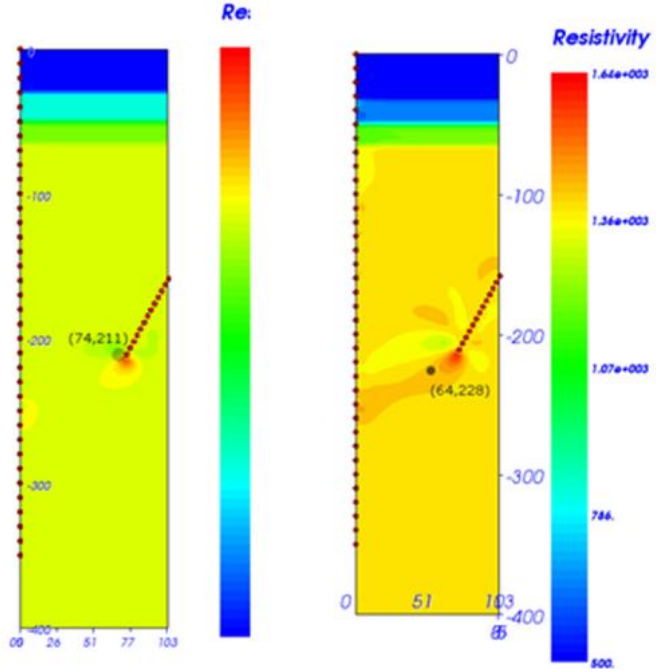
Conditions: CO2 at P = 30 atm, T = 18 °C:

ρ = 68.178 kg/m^3,

Porosity = 9%

Resistivity = 100 000 Ω*m

Discretization of the model: dx = dz = 2.5 m

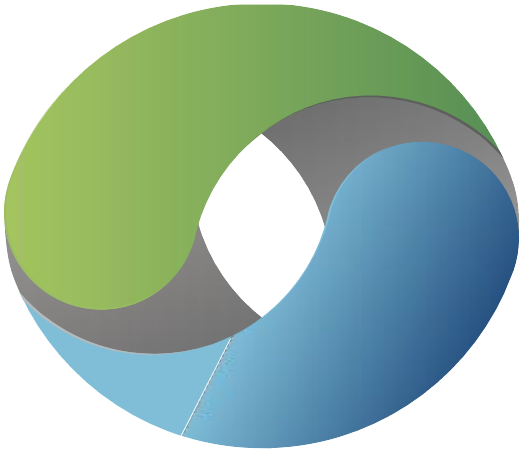


Synthetic tests CO2 observation by ERT in different configurations

Conclusions

- **HR1** SFL with two wells
- Initial vertical well **W1** provides VSP and well information
- Update geophysical characterization at depth
- Optimize fault drilling **WI** well plan
- Optimize instrumentation design of inclined injection well **WI**
- CO2 injection plan depends on encountered formation properties
- Well monitoring and time lapse related to injection plan

THANKS FOR YOUR ATTENTION



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