BOREHOLE GEOPHYSICAL CHARACTERIZATION IN THE FRAMEWORK OF THE ENOS PROJECT

MONITORING FEASIBILITY AND INITIAL RESULTS

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2nd Workshop of ENOS Experience-Sharing Focus Groups
Venice, 23 April 2018, 14:00 – 17:00
"Advanced techniques for site characterisation"

ENOS

Outline

Hontomin site **geophysical characterization** by:

- Innovative 3D VSP monitoring (**ENOS WP1 Task 1.3.2**)
- Pre-survey analysis of existing geophysical data
- Pre-survey reservoir model analysis
- Survey design and in-field quality control (**QC**)
- Survey description and main results
- 3D VSP data editing, processing, analysis and preliminary seismic results

Next project steps and data integration (**ENOS WP1 Task 1.4.1**)

Innovative 3D VSP monitoring by DAS instrumented well

- Use of fiber optic acoustic sensing (iDAS) technology available at Hontomin by permanent installation to measure 3D VSPs around the CO_2 injection well (HI)

- Base 3D VSP survey acquired in September 2017
- Subsequent continuation of injection activity (CIUDEN)
- Repeat (time lapse) 3D VSP survey planned in 2019

Hontomin 3D VSP acquisition

Contributions

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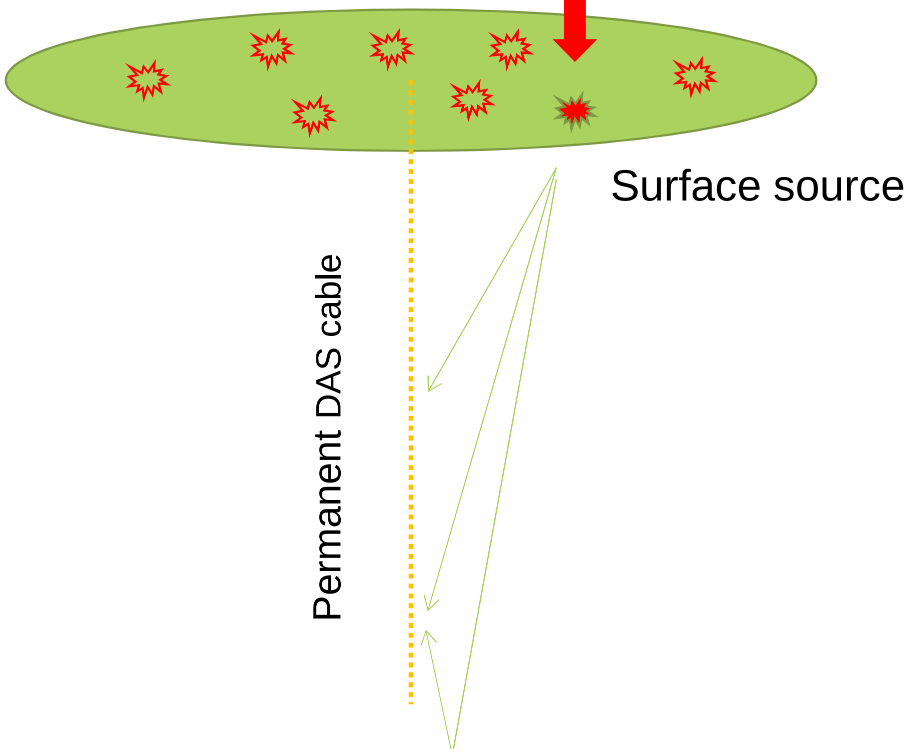
- Two seismic vibrators as seismic source at surface



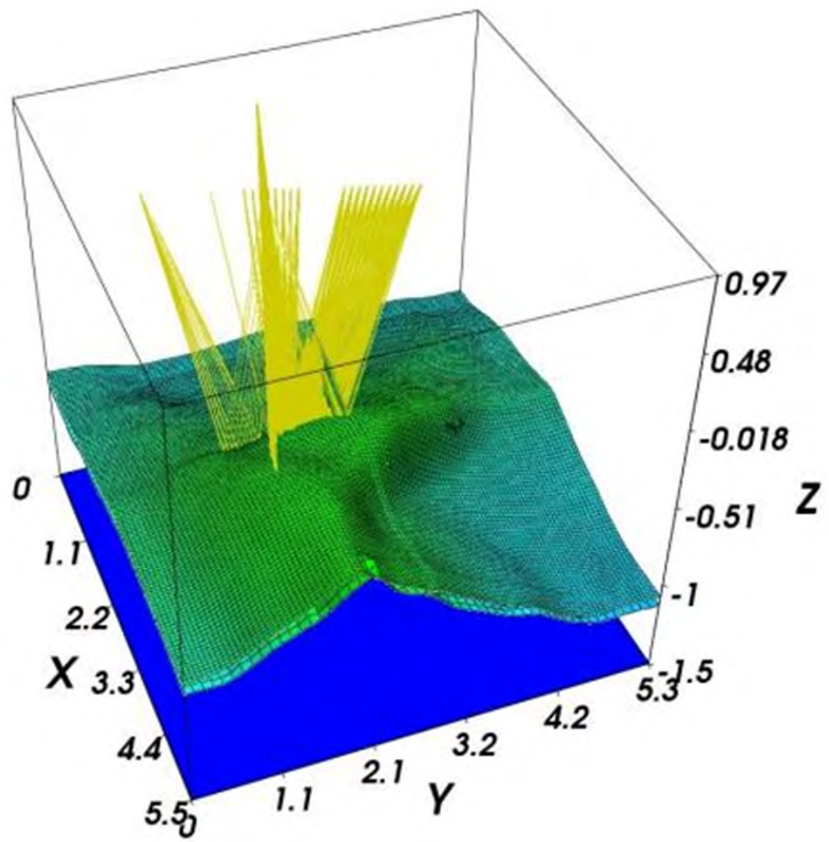
- Use of surface sources and permanent distributed acoustic sensors (iDAS)
- DAS cable installed in the injection (HI) well from surface to 1465 m depth
- Well receiver interval ~ 0.5 m
- Number of optical receivers 2893
- One surface-source position → One single VSP
- Areal distribution of sources repeated at surface → 3D VSP

Design of surface-source (shot points) acquisition map

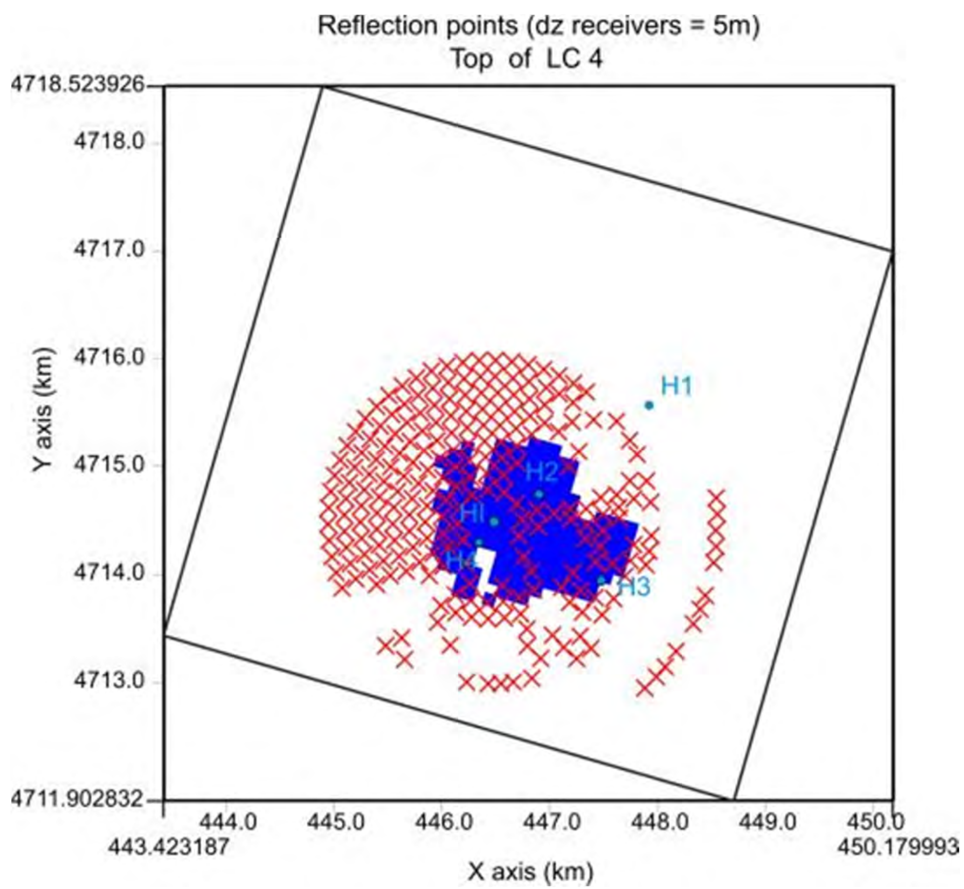
- Analysis of existing geophysical data (from CIUDEN)
- Pre-survey reservoir model analysis
- Use of plume model simulation results (actual and maximum expected extension after 10 k ton CO_2 injection)

- Needed to evaluate 3D VSP illumination zone at reservoir level, for its
  - Coverage at depth
  - Extension

thus design source point grid, according with survey parameters and plan a)



b)



a) Illumination analysis (using velocity structural model from existing 3D surface-seismic, logs and previous single-offset VSPs).

b) Example of source grid (red crosses) and calculated reflections points (blue) at depth

Design of shot point (SP) acquisition grid: summary

- Based on pre-survey model analysis for base and time lapse
- Considering the need to cover extended offsets
- Taking into account iDAS cable sensitivity response
- Considering different incident angles for direct and reflected events
- Assuming presence of reflection and also refraction events for structural investigation at depth

- Decision to design the survey also with large offsets and with complete azimuthal disposition, according to field-access conditions

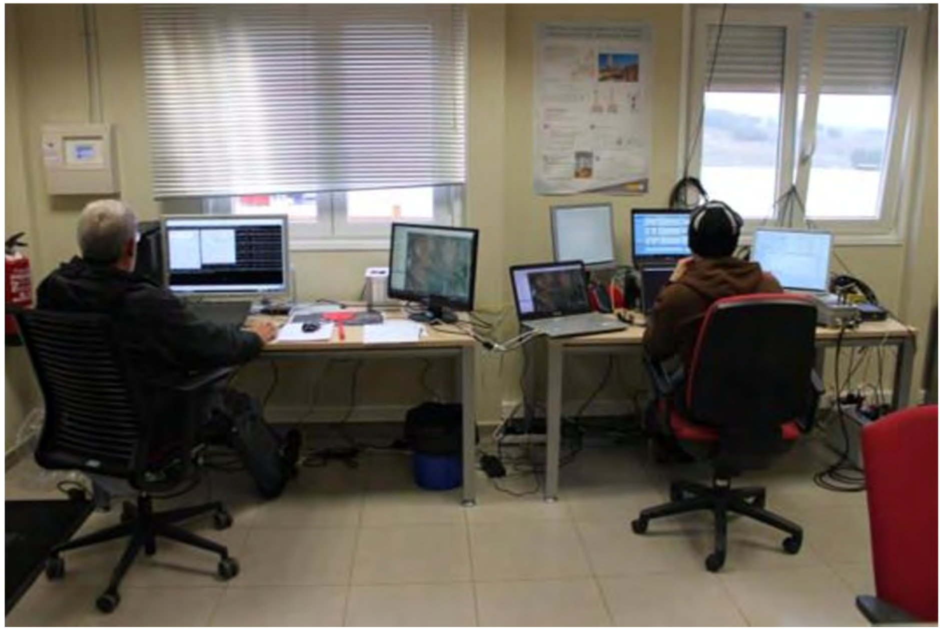
Main acquisition parameters

Source parameters:

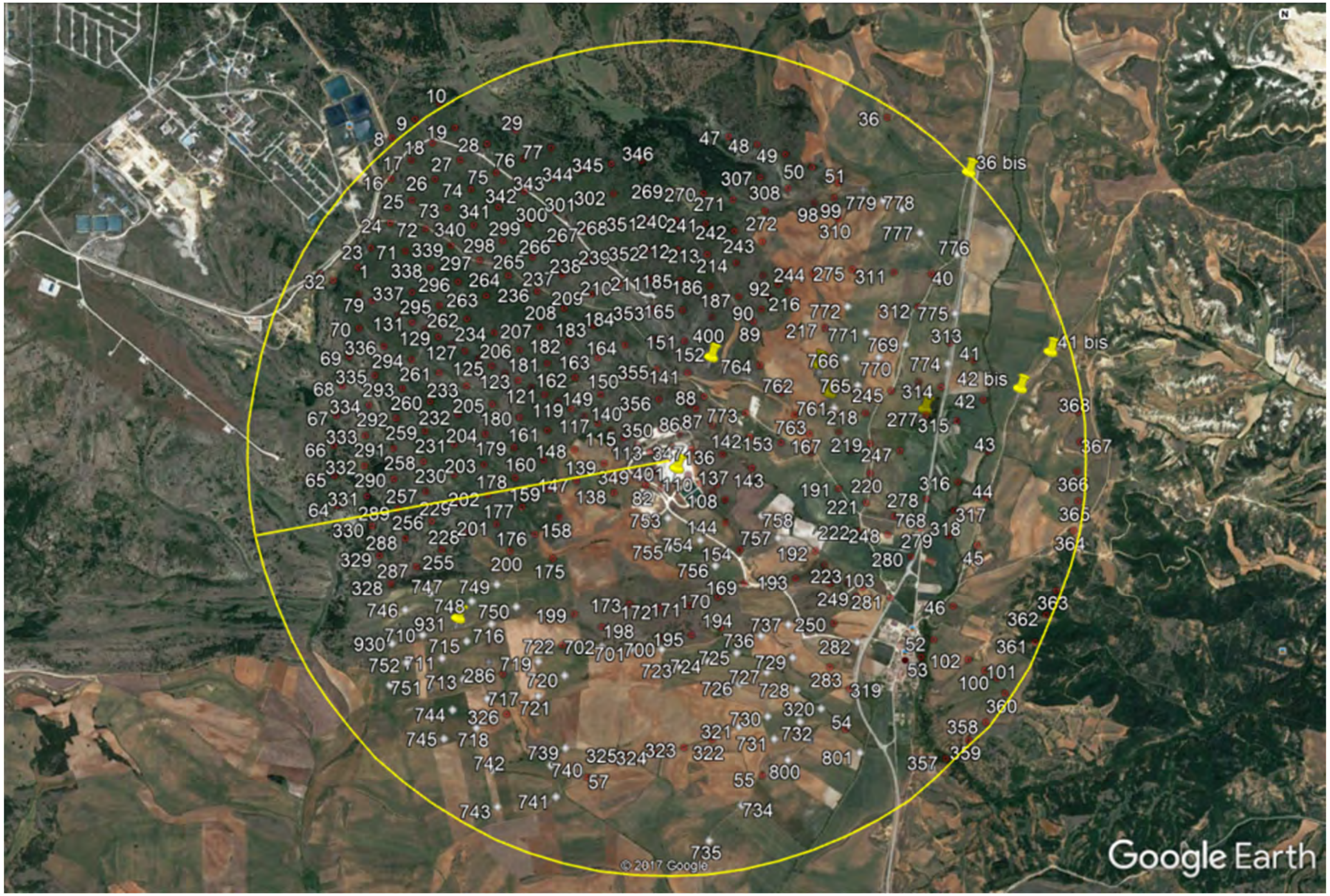
- Two vibrators at the same shot points (SP)
- Sweep duration 16 s
- Sweep frequency 8 – 128 Hz

Recording parameters:

- 20 s recording time
- 12 vibrations per shot point (production) stack
- 3 vibrations per shot point (QC) stack



- **Field QC and survey operations**
- **Source control and Silixa data transfer**
- **In field QC by 3-shots per SP**



- Map of acquired SP
- Total no. 390 SPs
- Including “wide offset”
- Maximum offset ~ 2.1 km from HI wellhead
- 2.1 km circle in figure

Summary of 3D VSP acquisition survey results

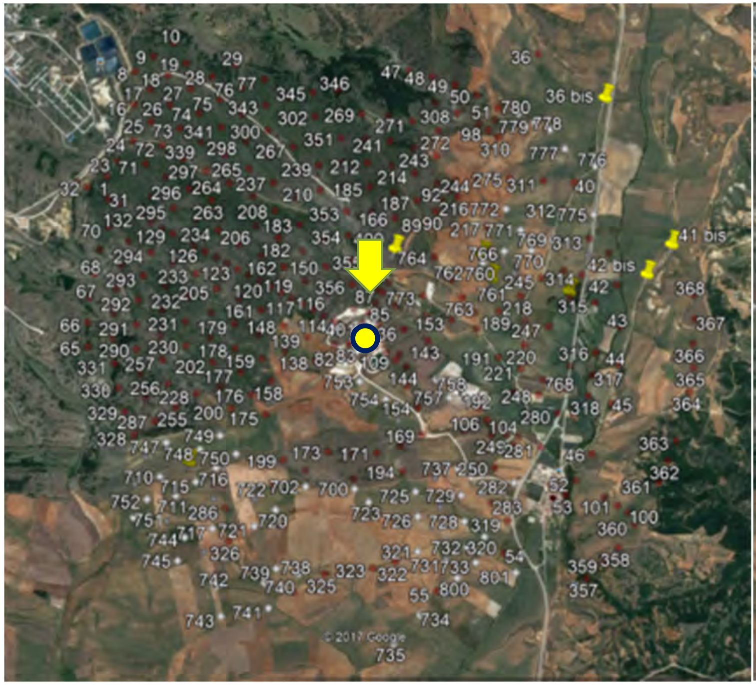
- Approximately 12-days of survey duration
- Acquired 390 SPs, i.e., 390 VSPs, at different offsets and azimuth

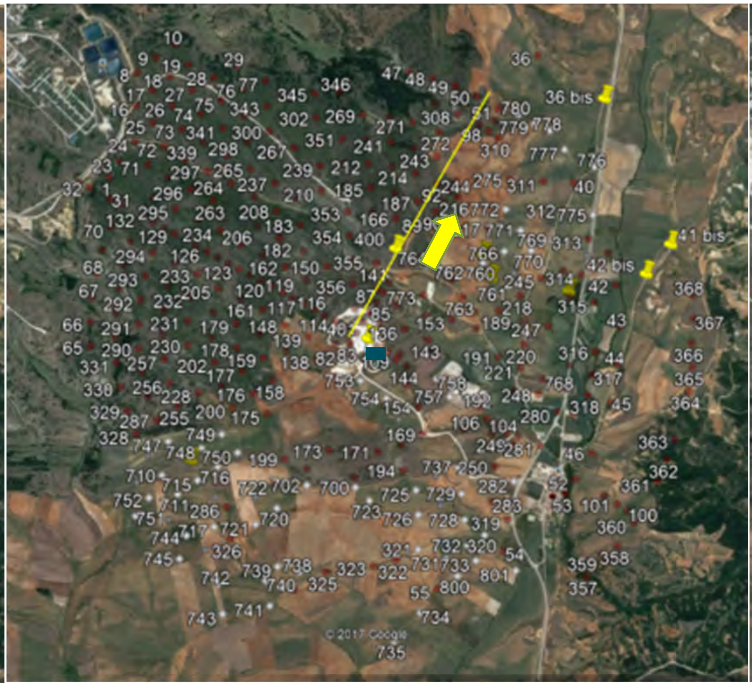
Total number of acquired traces: ~ **1.130 Mega**

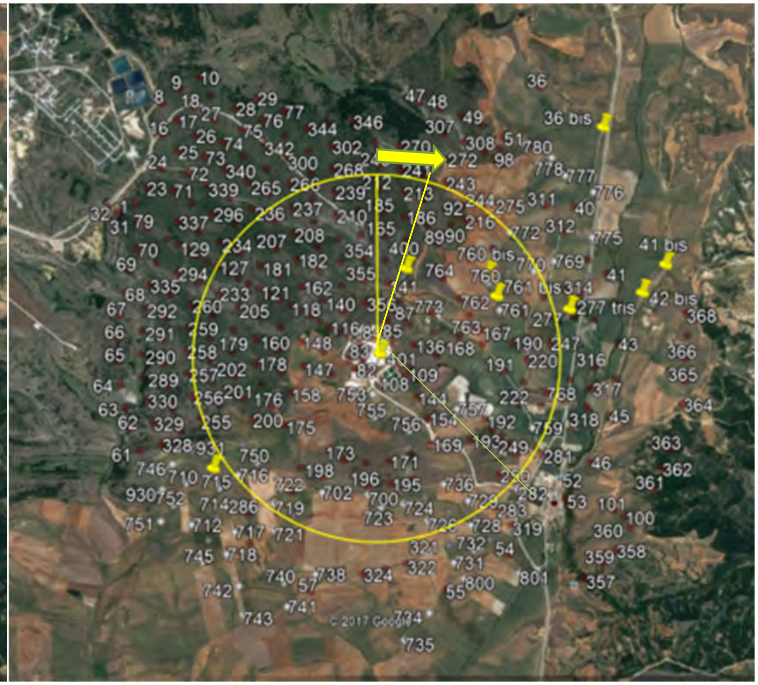
Data quality: Good, ranging from High-quality to lower quality signals (depending on SP, offset, azimuth and event type)

- Including direct, reflection and refraction signals
- Including signal variations due to presence of fractures and faulting

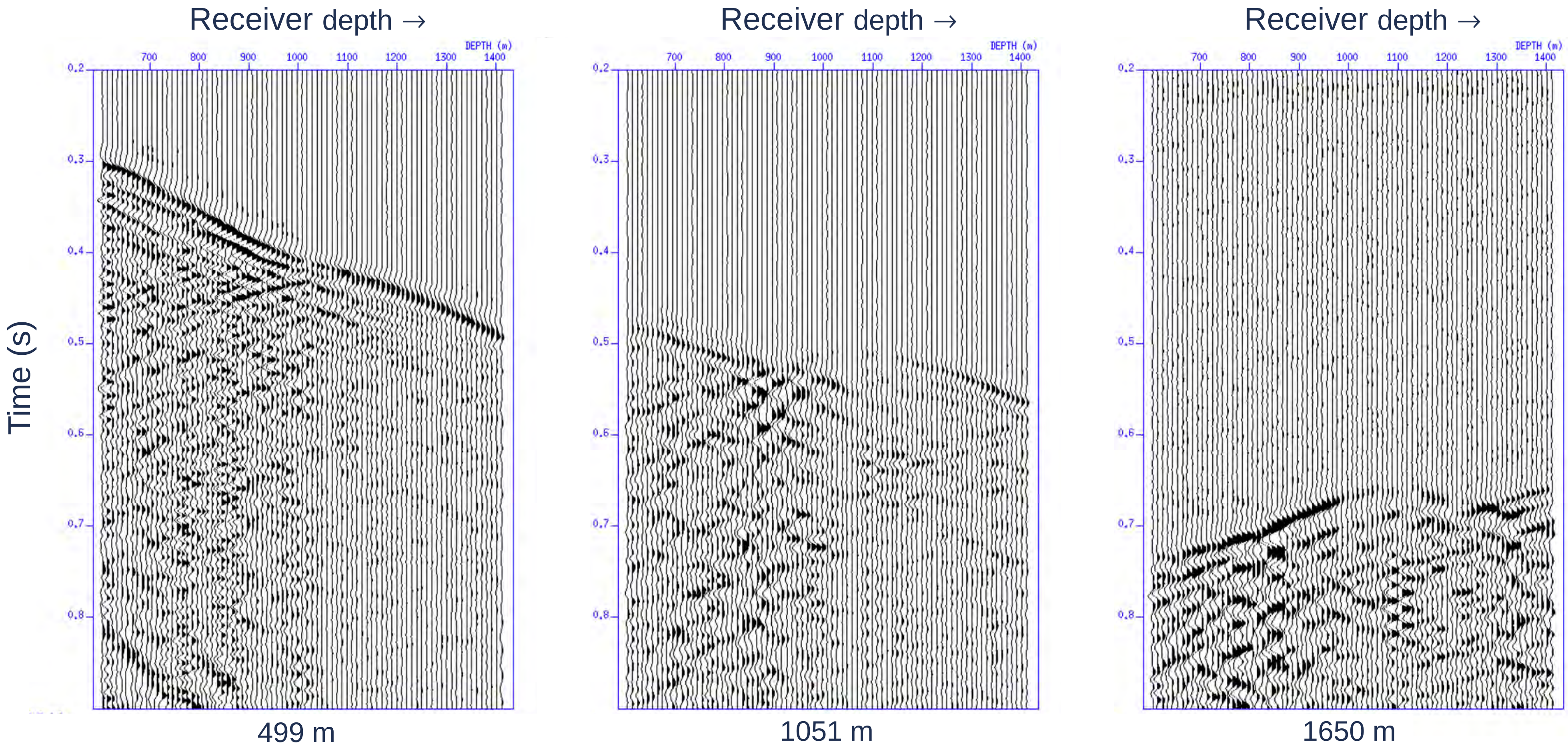
3D VSP dimensions: depth, offset, azimuth


depth

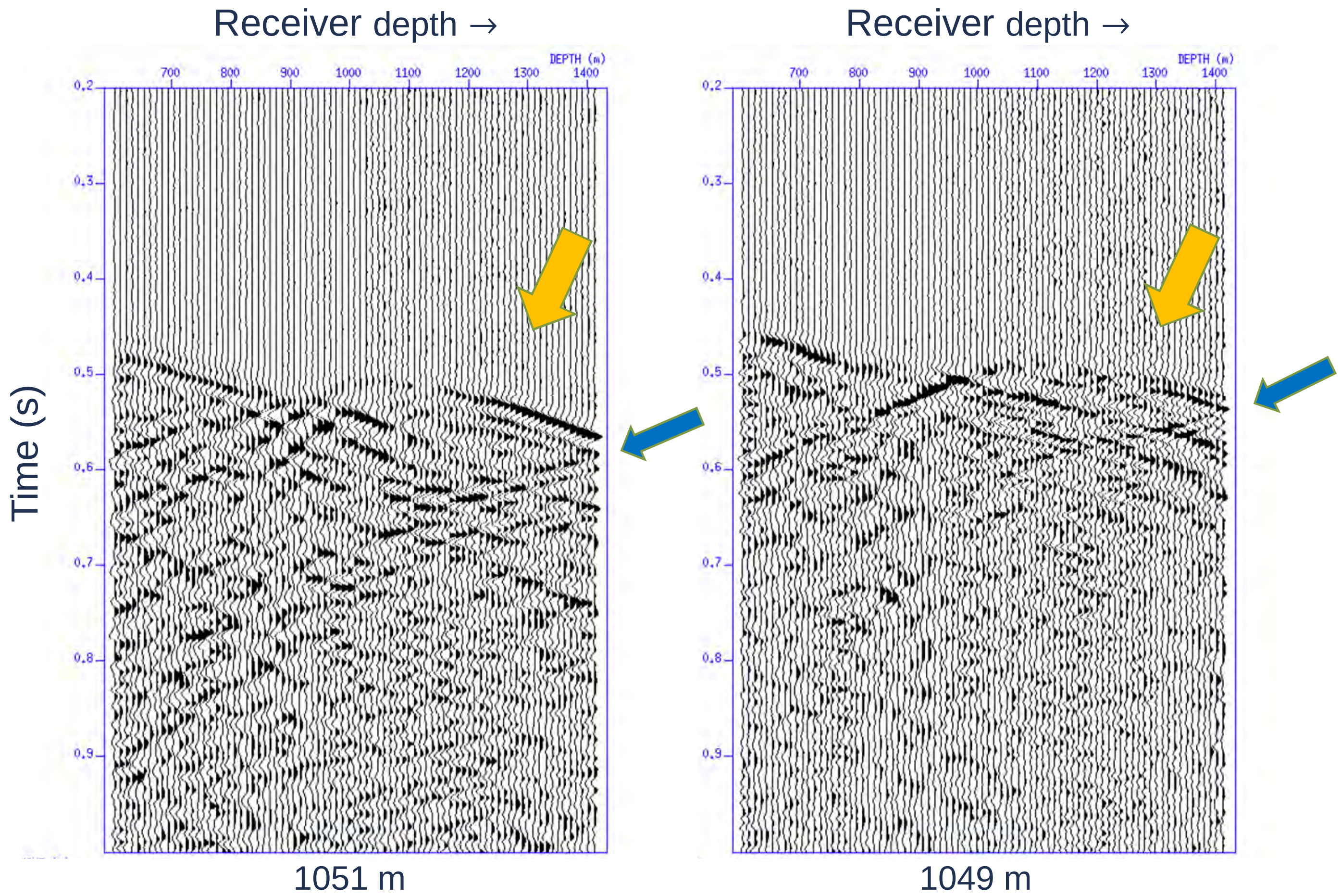

offset


azimuth

QC examples (10 m plot) : ~ same azimuth, different offsets



QC examples: ~ comparable offsets, “orthogonal” azimuth



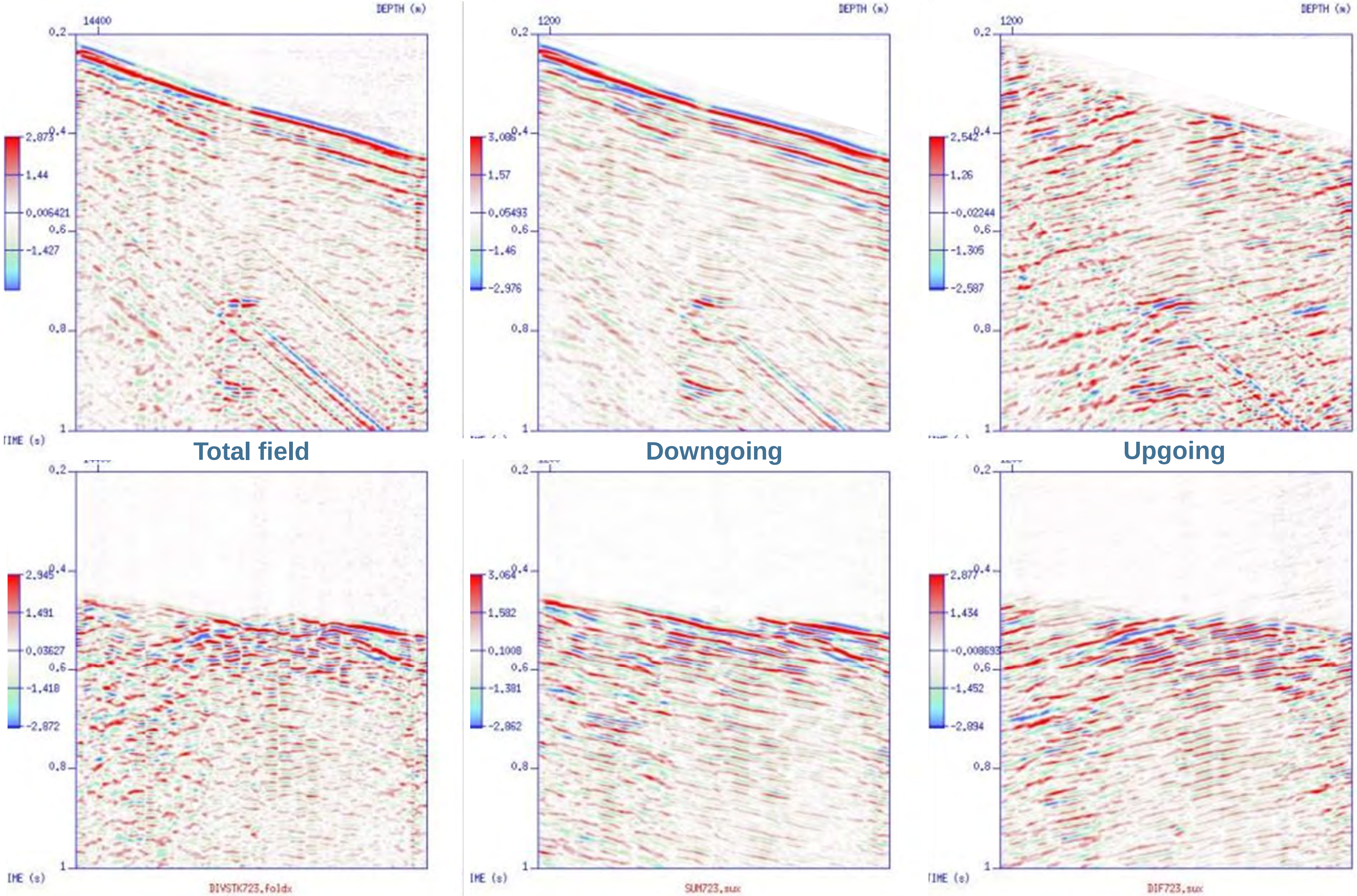
WAVEFIELD SEPARATION

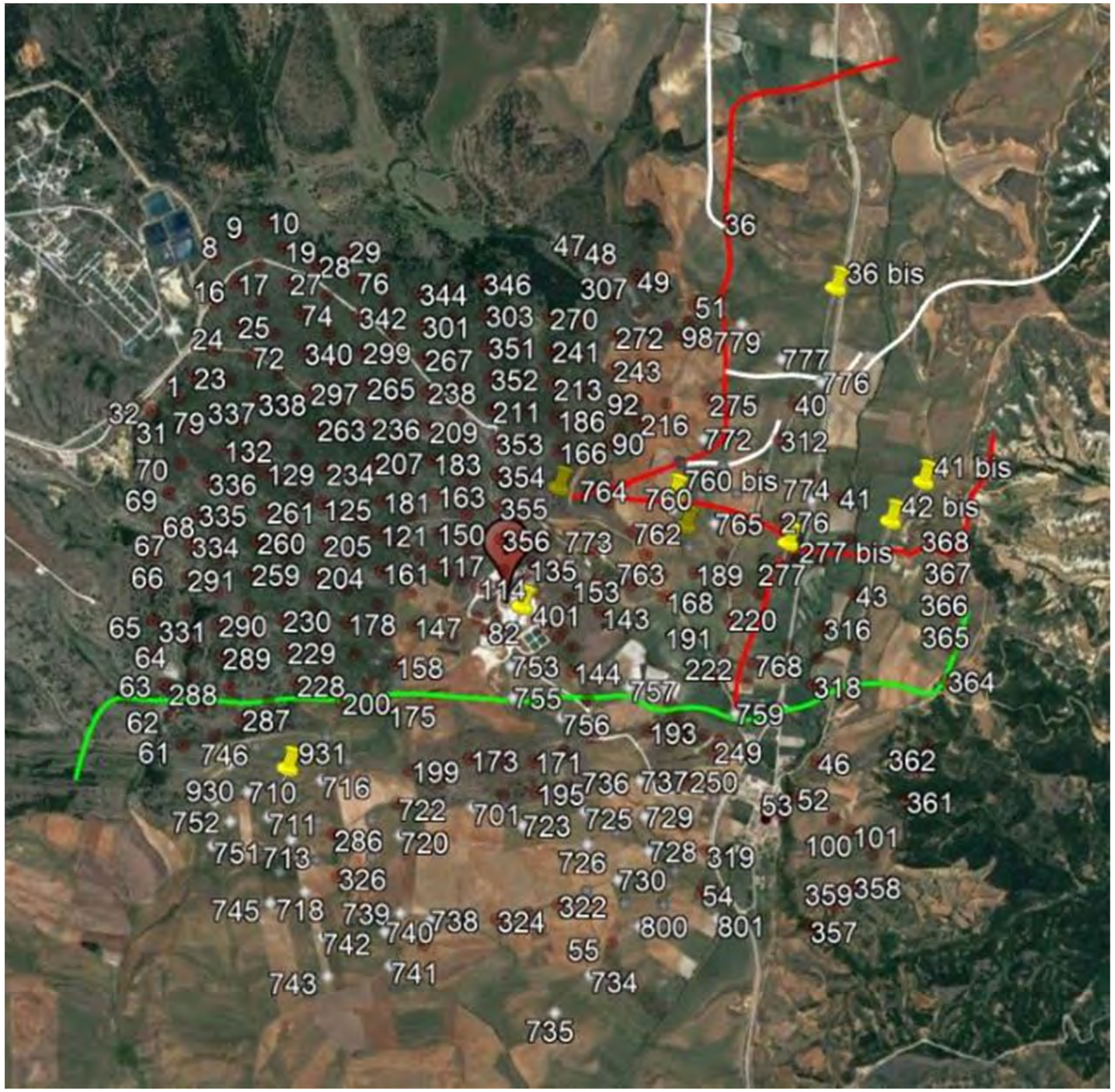
- **Key role** of borehole wave-field separation for **Reservoir** analysis
- Use of **dual wave-field** method (Poletto et al. 2016, Geophysics)
- Based on calculation of dual velocity signal from native strain (DAS)
- Effective thanks to dense receiver array (trace interval 0.5 m)

- Very robust (also when direct wave is weak and at large offsets),
- Applied without need of signal picking
- Provides **DOWN-going** and **UP-going** separated wave-fields
- Used for all the VSPs of the 3D VSP dataset

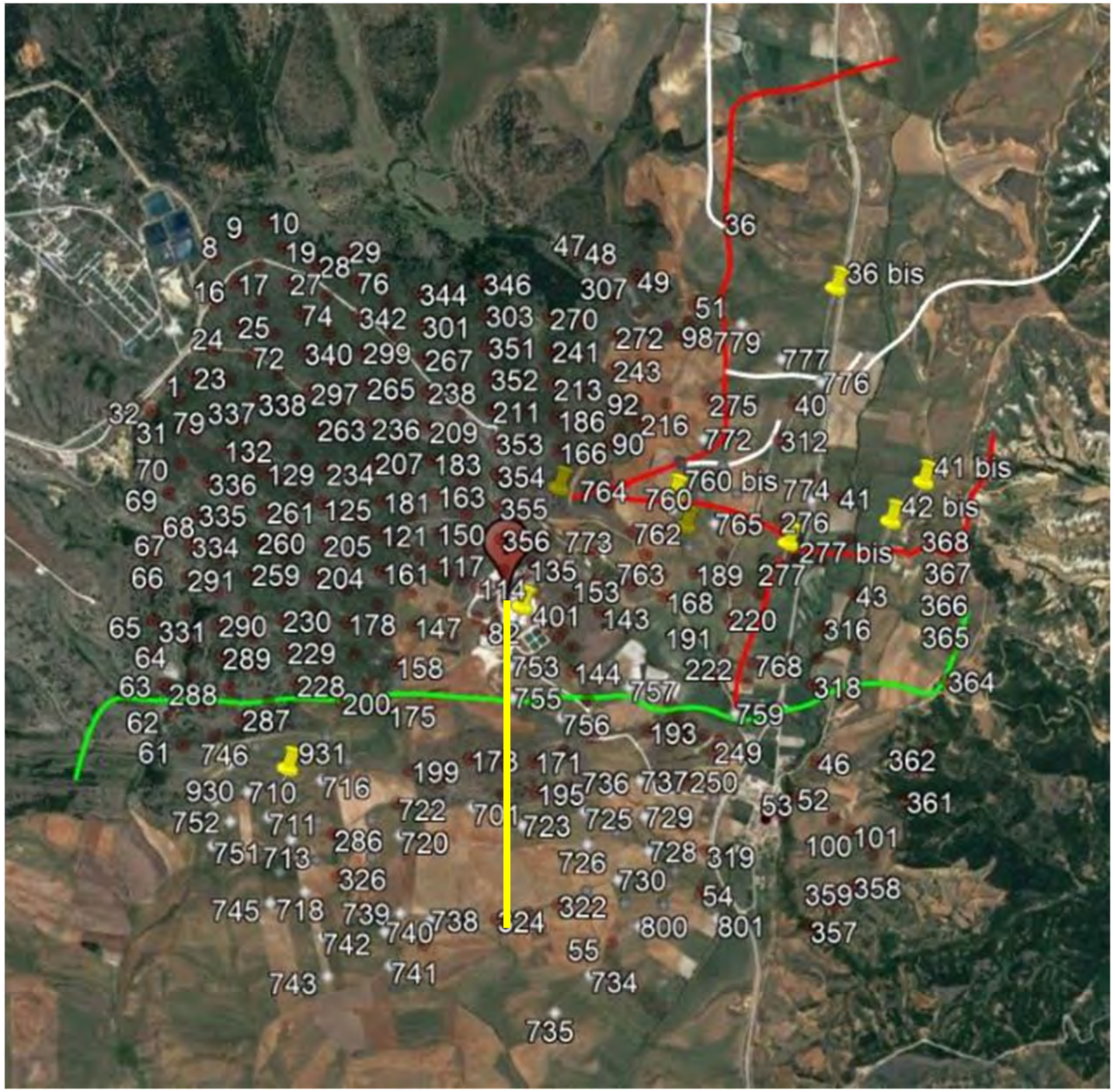
Short offset (149 m)

Medium-far offset (1049 m)



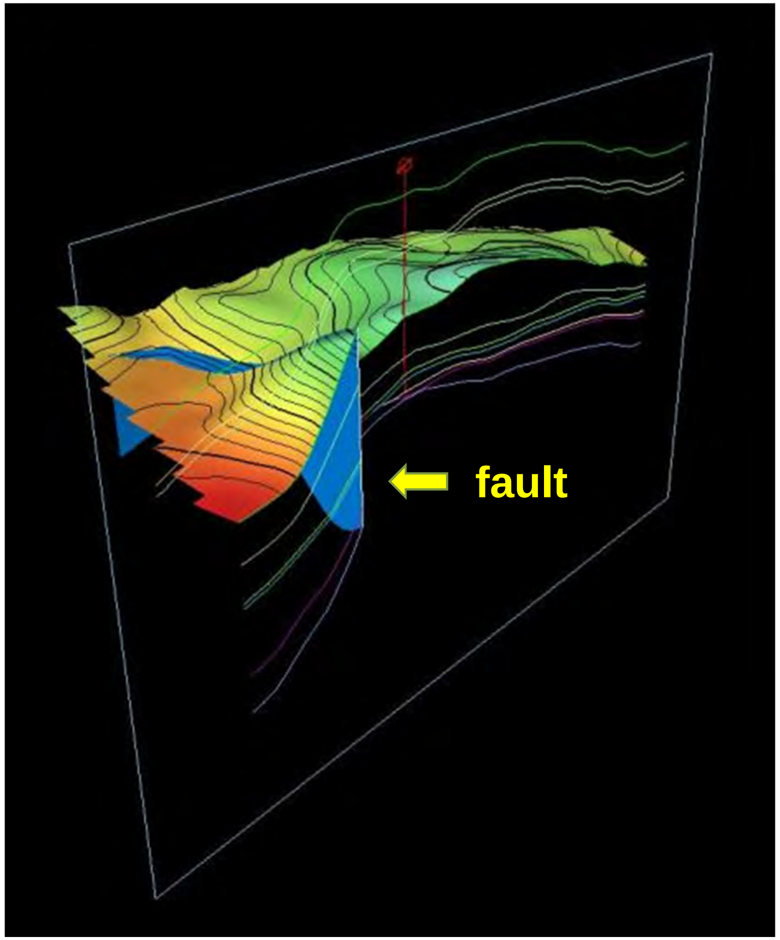


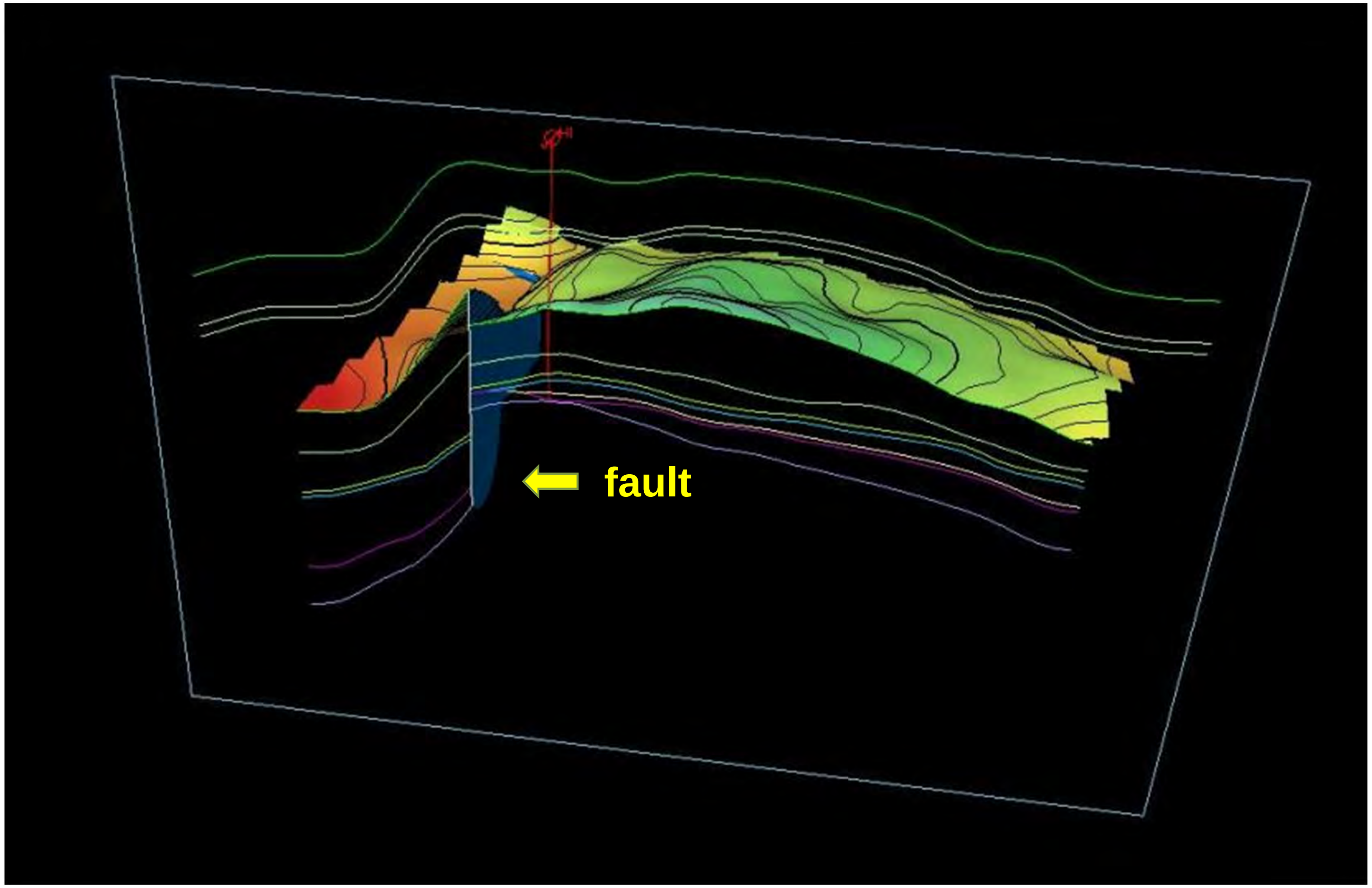
3DVSP map and main fault's system



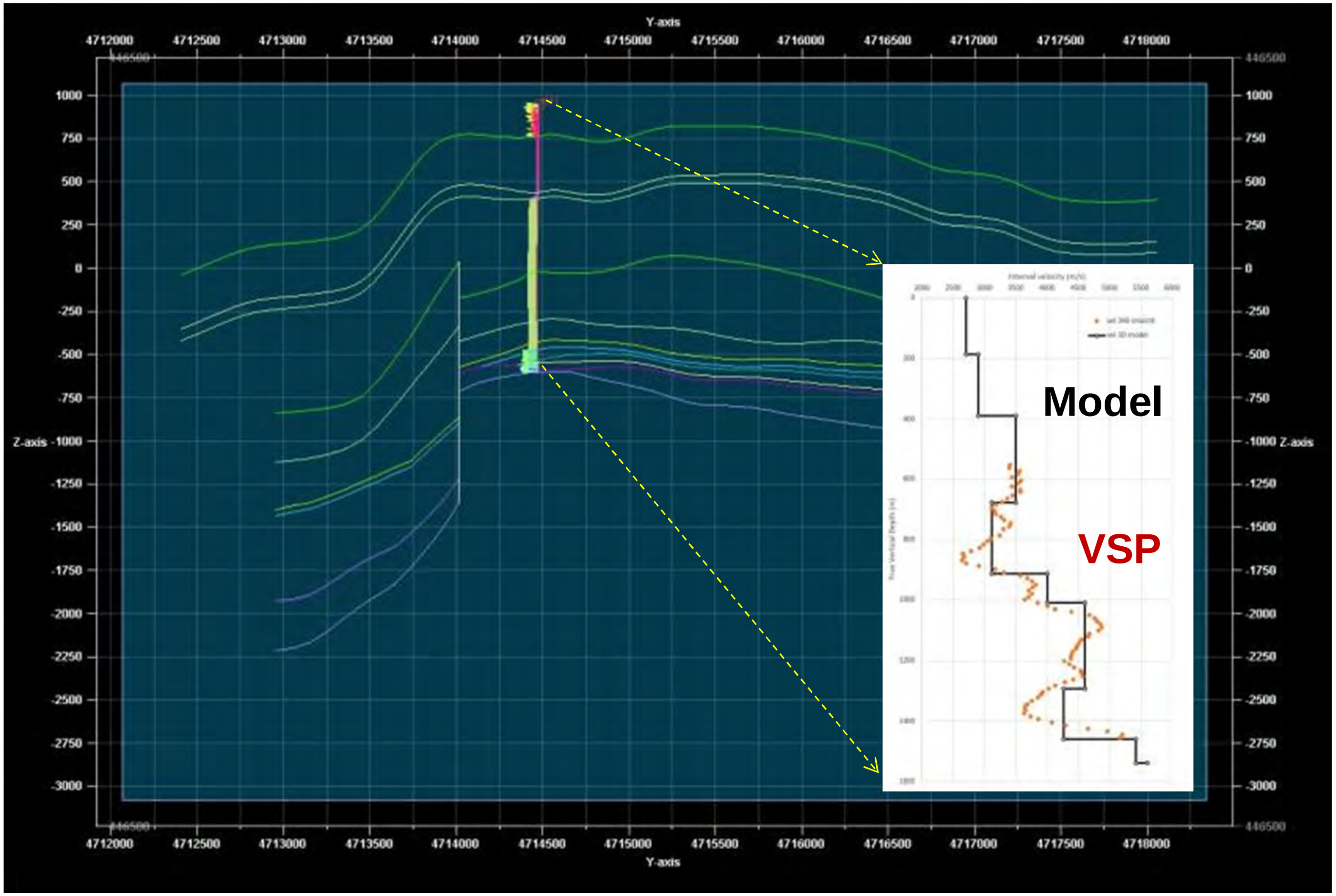
Select shots on 'south' investigation (yellow) line (normal to fault)

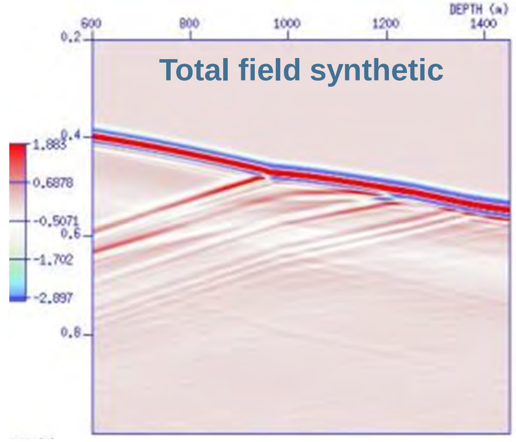
Sud-North section and selected fault from Petrel model

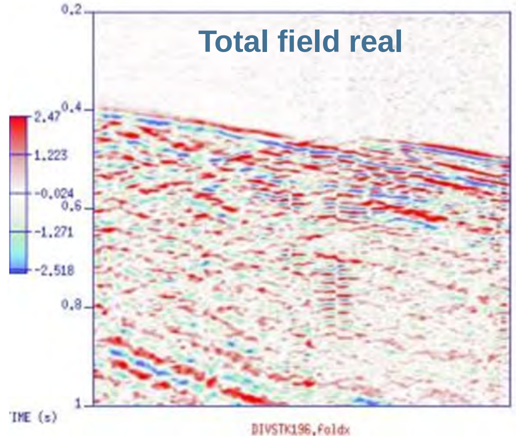




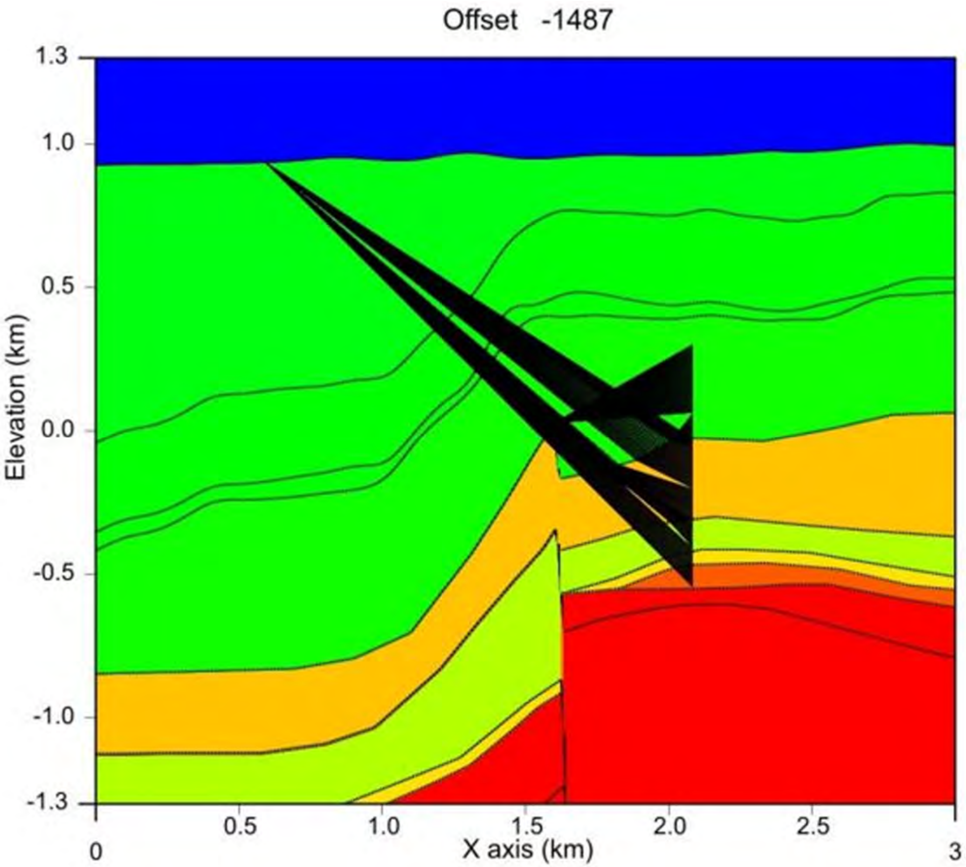
Sud-North section, velocity calibration and synthetic model

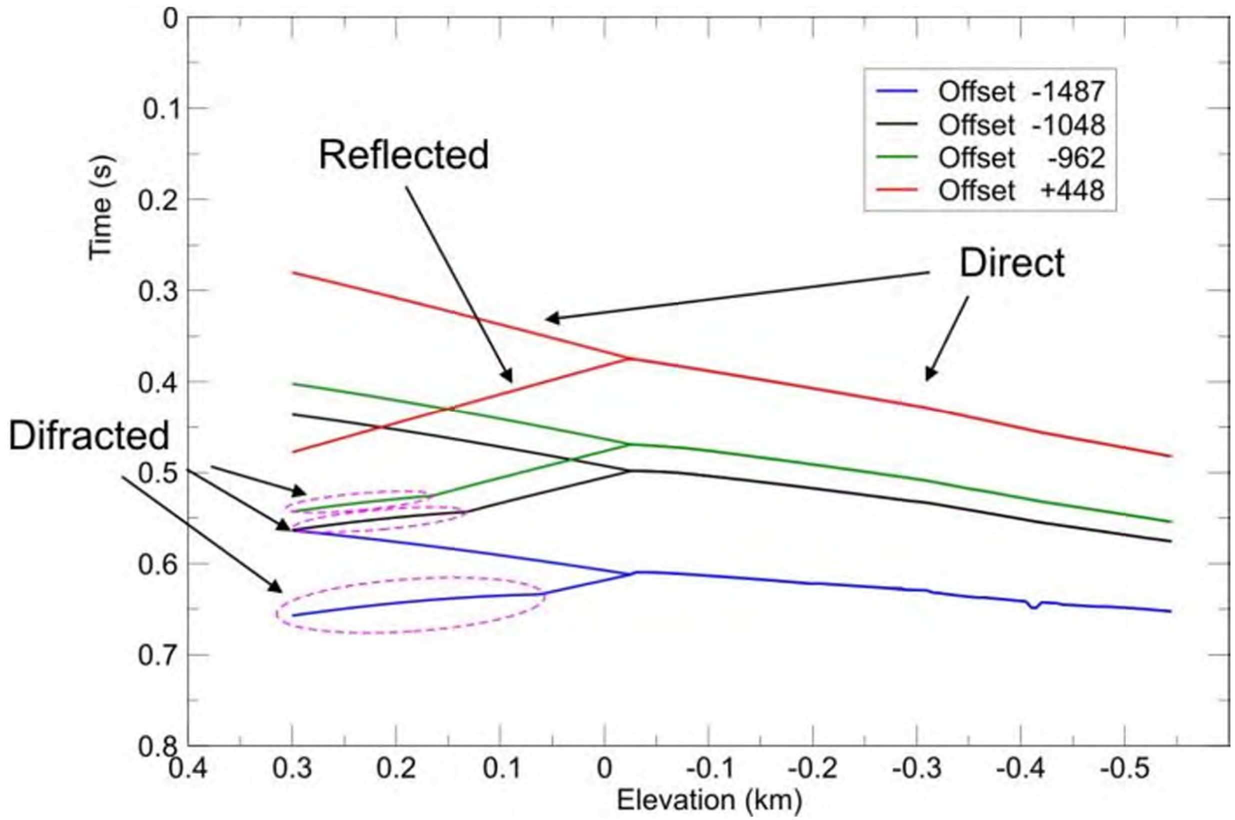






Ray tracing and wave's interpretation (including fault's diffractions)





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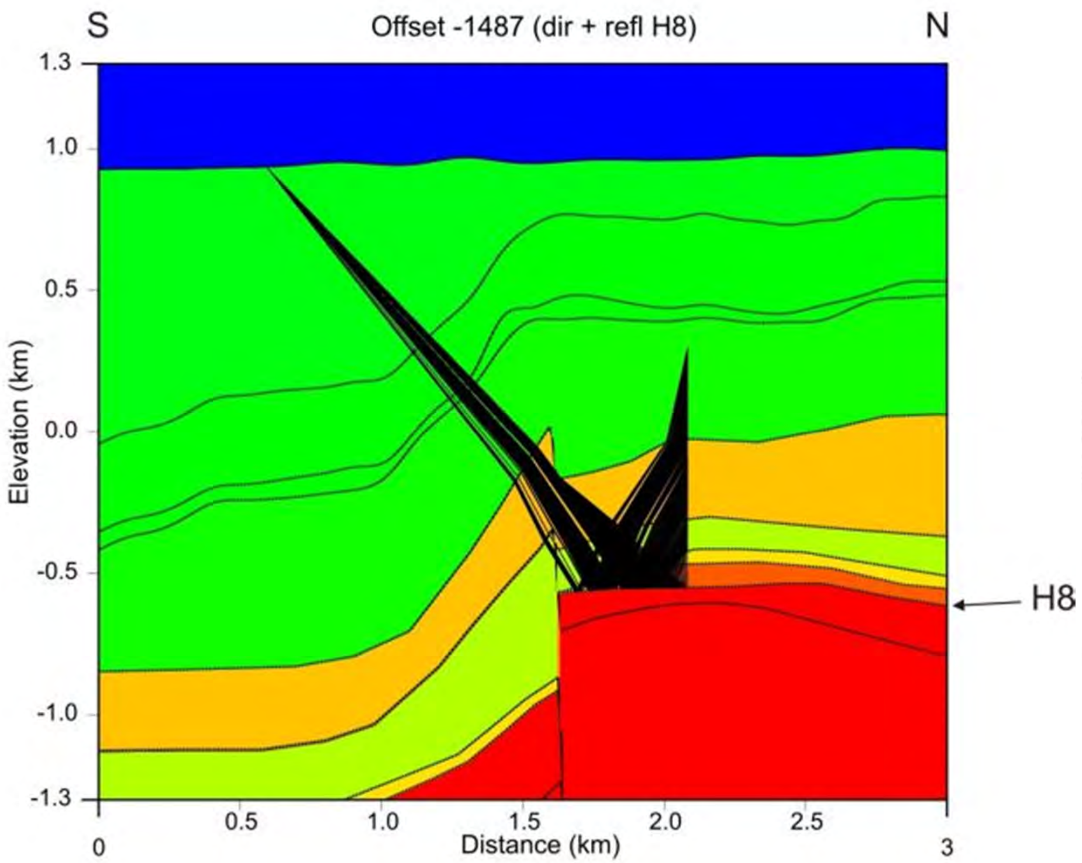
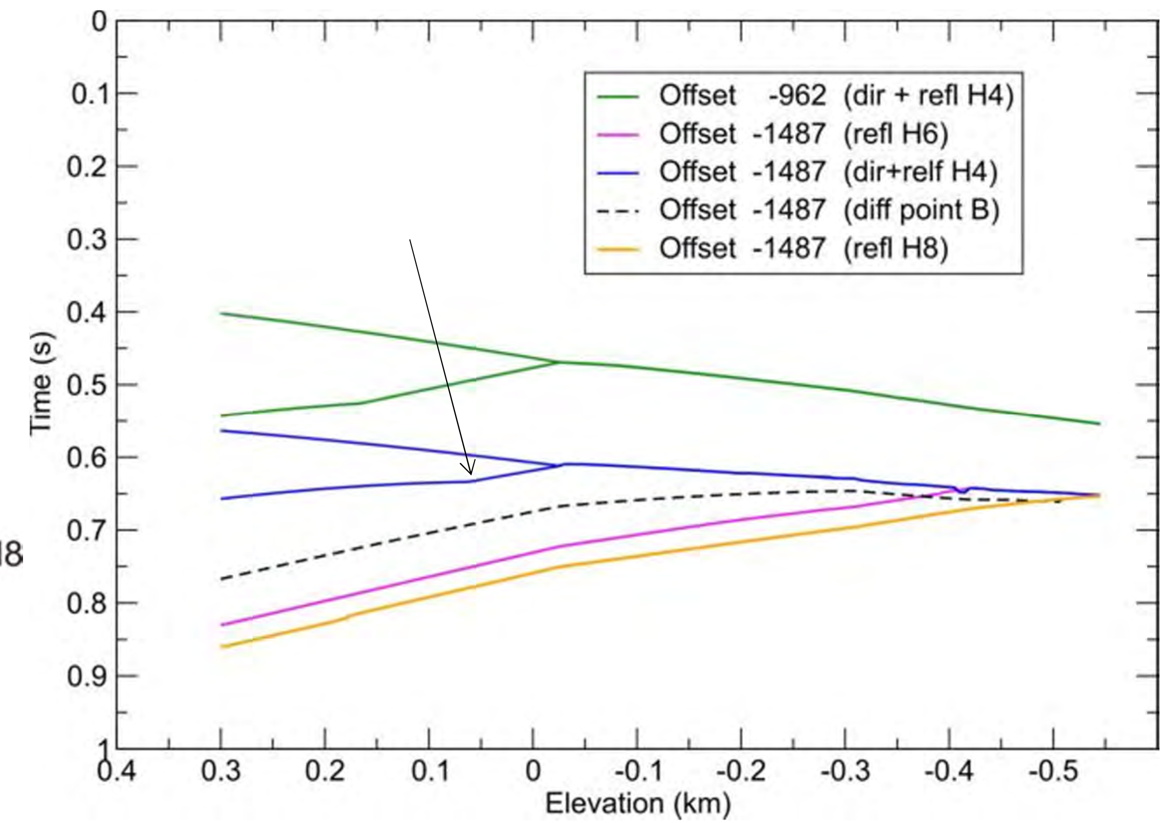
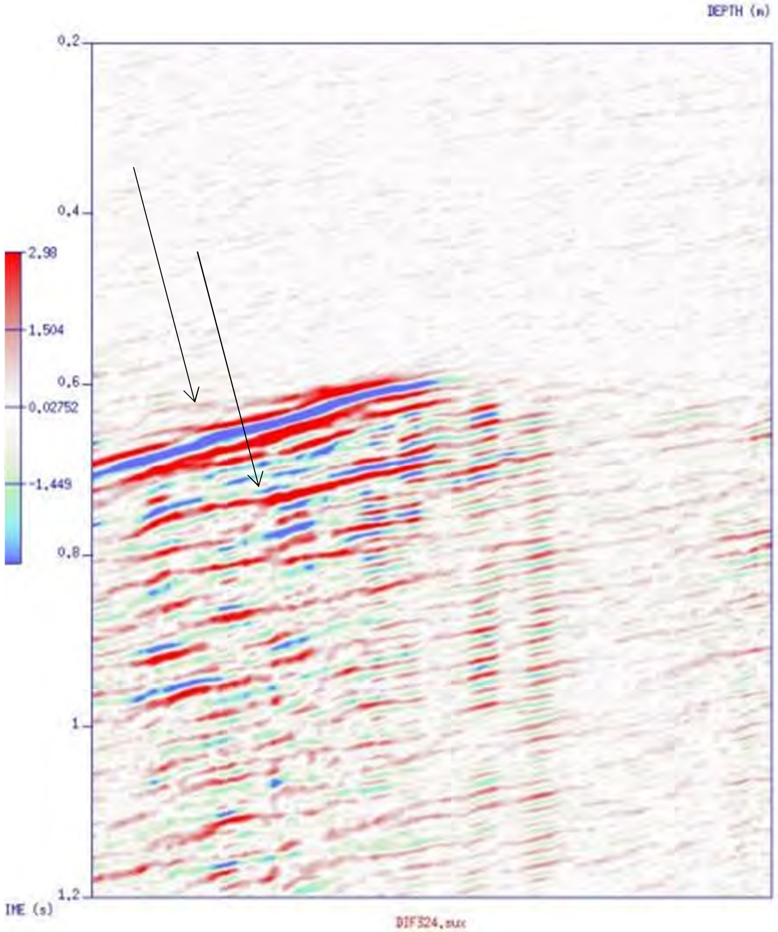
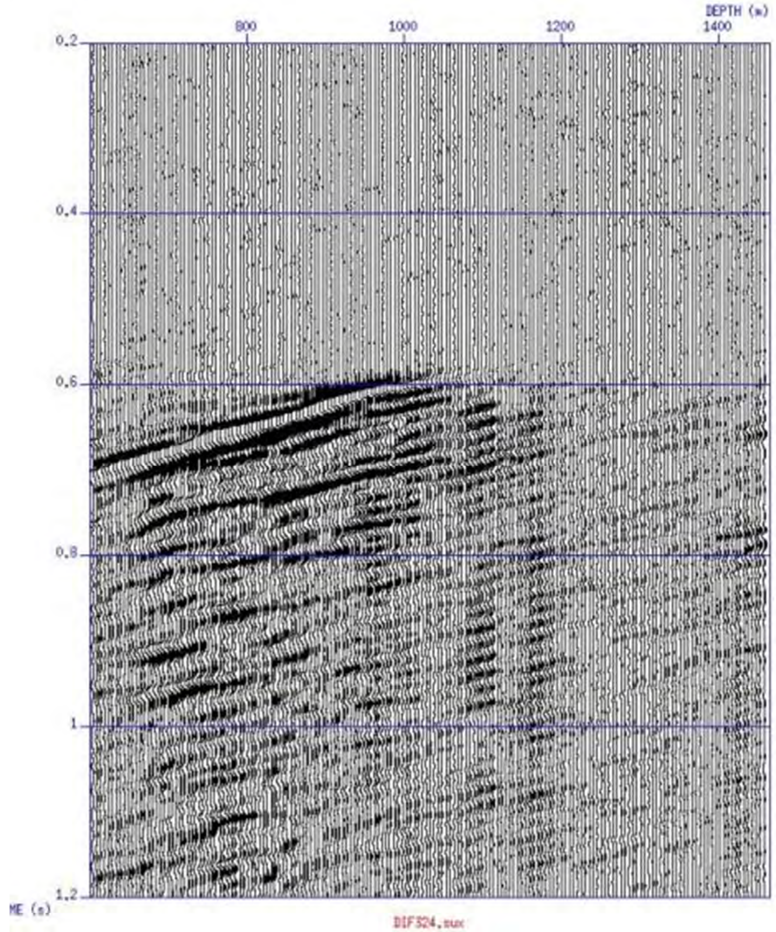




Upgoing wave’s interpretation (including fault’s diffractions)





RESULTS AND NEXT STEPS

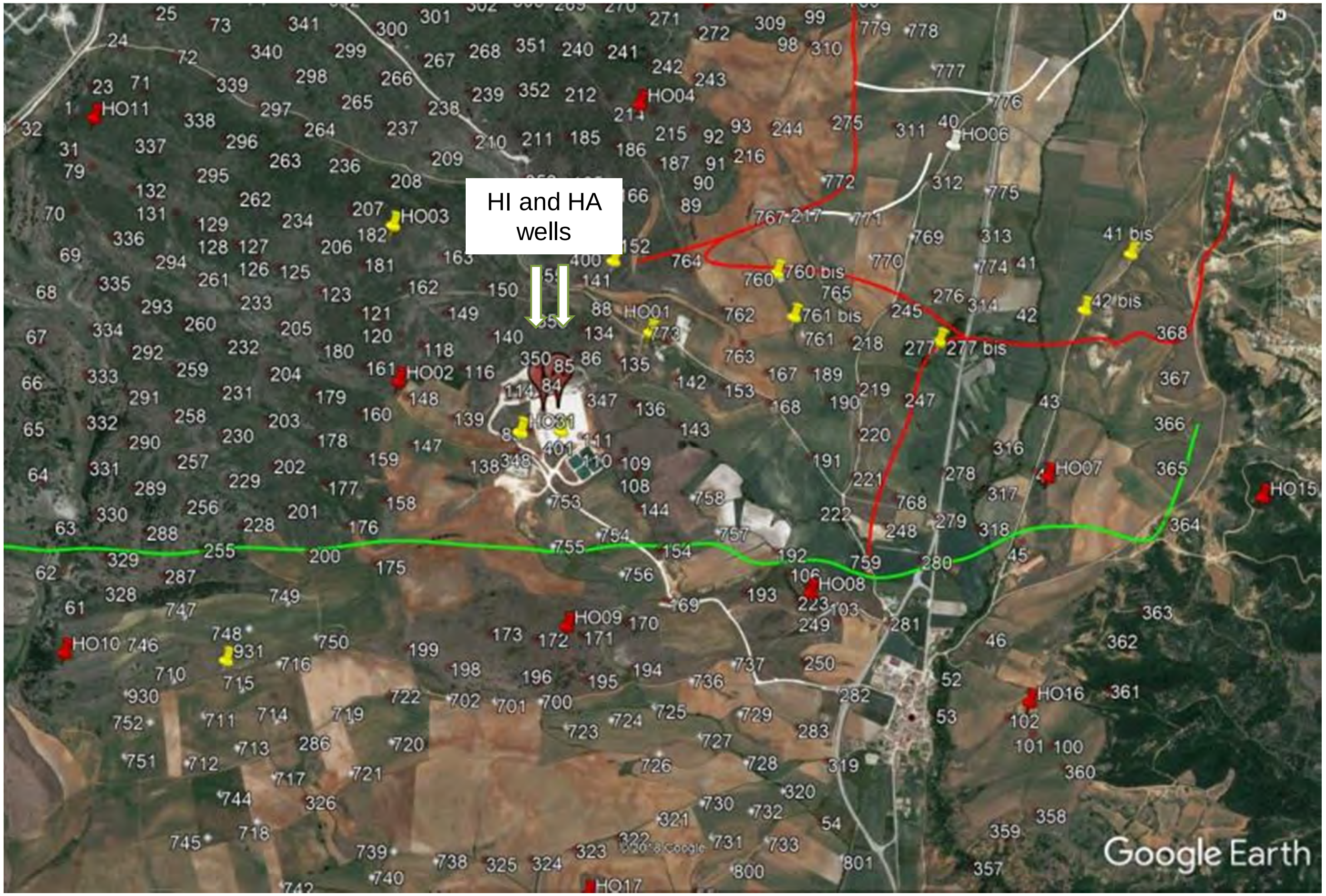
- Completed editing of iDAS 3D VSP field data
- Completed data correlation and stacking, (dual) wavefield separation
- PROVISIONAL RESULTS: fault's and reservoir observability

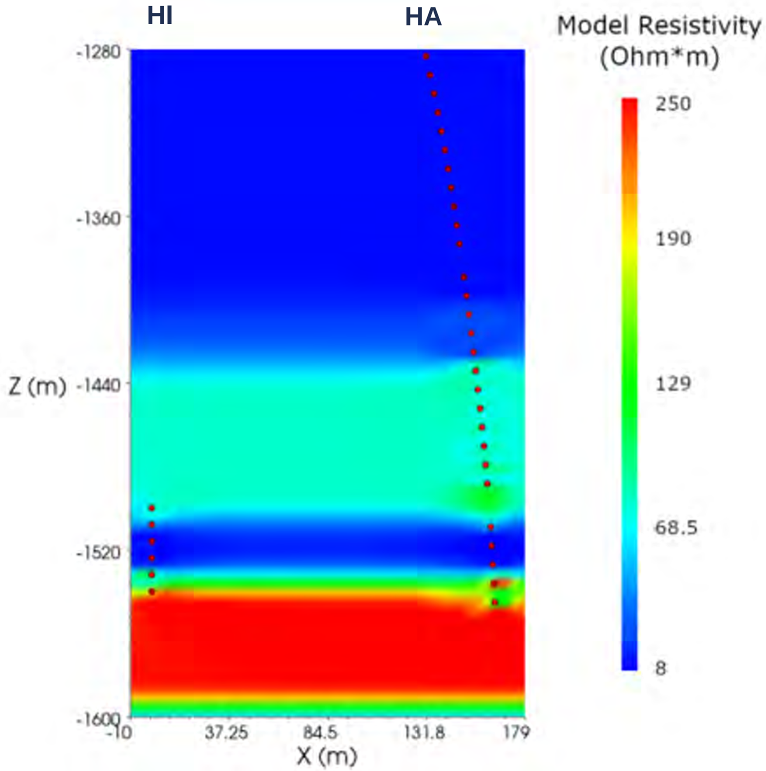
- NEXT STEPS: in progress 3D VSP data processing for base **static** model characterization, including faults and reservoir, calibration of velocity model (**tomography**), provide structural info at depth (wave-field's and reflection processing, **migration**)

- Data **integration** (T1.4.1) and joint interpretation (ERT and Micro-seismic), injection data

- Use 2017 survey results for planning of the next 3D VSP survey (2019)
- Analysis of **dynamic** model

DATA INTEGRATION (WP1 T1.4.1)





Example of cross-well ERT inversion (resistivity model from Ogaya et al. 2016)

Conclusions

- Base 3D VSP survey acquired in September 2017
- Data processing in progress for base-model characterization
- Repeat 3D VSP survey in 2019

- Integration with ERT well data
- Integration with micro-seismic monitoring data

THANKS FOR YOUR ATTENTION

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