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”

San Servolo, Venice, 23 April 2018
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 CO2 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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- 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

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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 CO2 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) 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

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- 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 azimuths

**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

<table>
<thead>
<tr>
<th>depth</th>
<th>offset</th>
<th>azimuth</th>
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QC examples (10 m plot) : ~ same azimuth, different offsets

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QC examples: ~ comparable offsets, “orthogonal” azimuth

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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)
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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

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

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

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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