Surface Seismic Monitoring of Near Surface CO2 Injection at Svelvik

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Introduction

A CO_2 migration field laboratory for testing monitoring methods and tools has been established at Svelvik, near Oslo (Norway). At the site, feasibility, sensitivity, acquisition geometry and usefulness of various surface and subsurface monitoring tools are investigated during controlled CO_2 injection experiments. The current study aims at assessing the sensitivity of geophysical methods to detect CO_2 accumulations at 65m in the presence of heterogeneous overburden

Conclusions

- To get the resolution aimed for the true model, we need to go beyond 100 Hz (very challenging with surface layouts)

→ Combination with crosswell/VSP layouts might alleviate this problem

- Very important to have the best possible baseline (very good results when the baseline is assumed to be known
- Diffractors on the weathered zone have an important impact on both the modelling and the inversion results.

Future work

- Svelvick CO2 FieldLab upgrade in progress !
- New Injection experiment at around 100m depth
- Drilling and completion of new monitoring wells equipped with fibre optical cables
- Acquisition design is key maximize the sensitivity of the geophysical methods to detect small CO2 plumes

→ Ideal place to test innovative acquisition systems and imaging/monitoring technologies

Background

In 2011, 1700kg of CO_2 were injected at Svelvik at 20m below surface to investigate the sensitivity of various monitoring methods to detect and quantify vertically migrating CO_2 through unconsolidated sediments (Barrio *et al.,* 2014). Even though all methods detected the presence of CO_2, the plume didn't behave as expected: its path was strongly influenced by geological heterogeneities

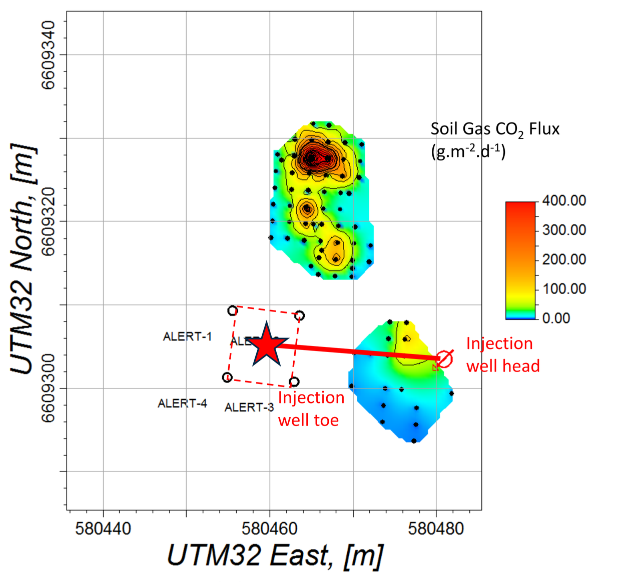


Figure 1 (left): Soil gas flux data taken the fifth day of injection showing 3 areas of gas escape E, NE and NNE of the main injection.

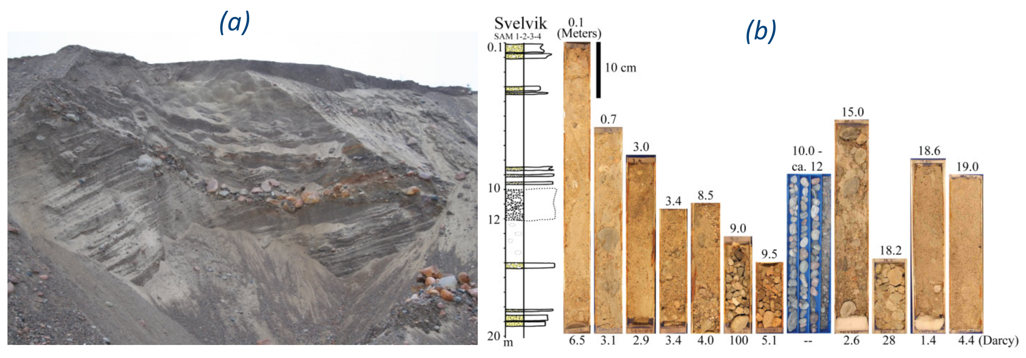


Figure 2 (bottom). Geological characterisation: (a) Outcrop of a sand deposit at Svelvik displaying laminated stratigraphy with pebble channels; (b) Stratigraphic log and samples collected a few meters to the side of the injection point after the injection test, arranged by increasing depth (value above each sample) and with corresponding permeability displayed (values, in Darcy, below each sample).

3D geomodel building

- Re-processing of appraisal 2D seismic was carried out to improve geological interpretation (Figure 3 and 4)
- Special focus was given into the integration of all available sparse datasets: (2D profiles, samples, logs…)

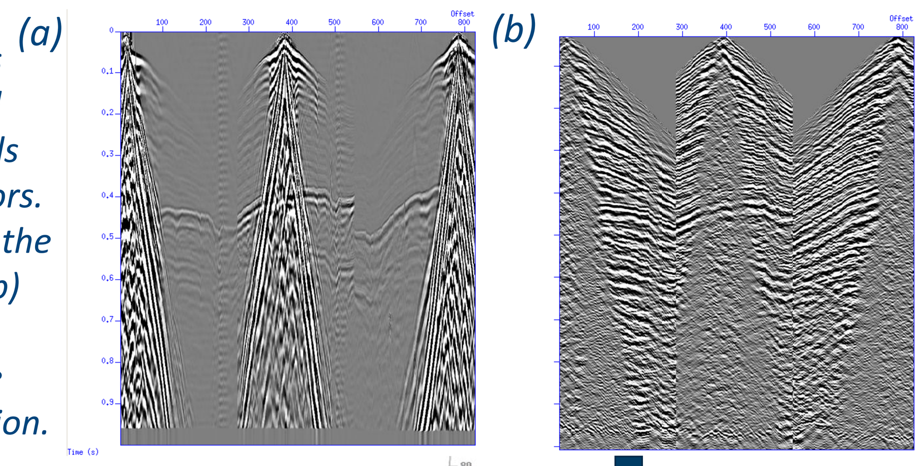
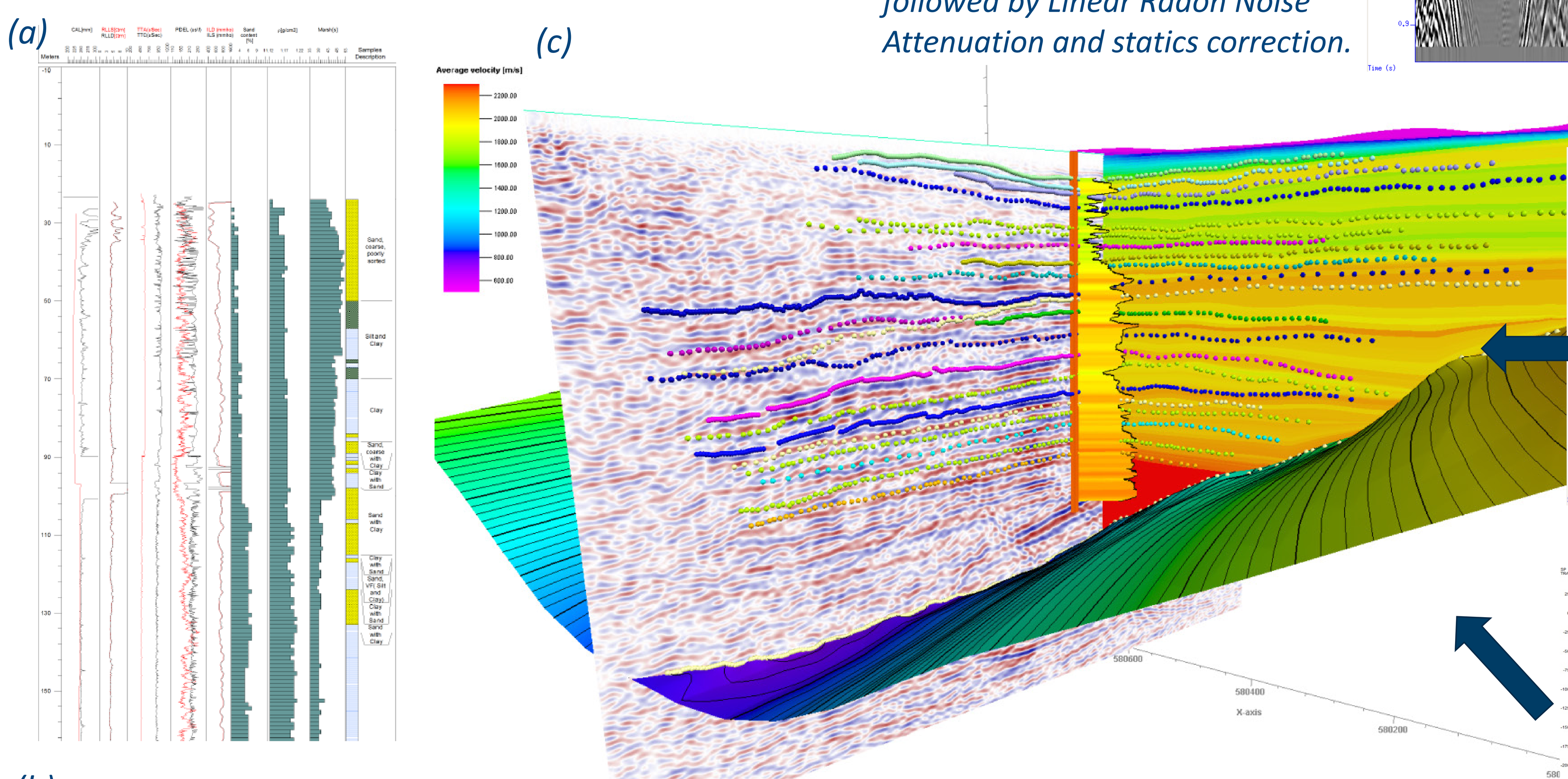


Figure 3: (a) 3 raw shot gathers exhibiting energetic ground roll and other surface waves arrivals masking the underlying reflectors. Notice also the strong effect of the topography on the reflectors; (b) Data after spectral balancing followed by Linear Radon Noise Attenuation and statics correction.



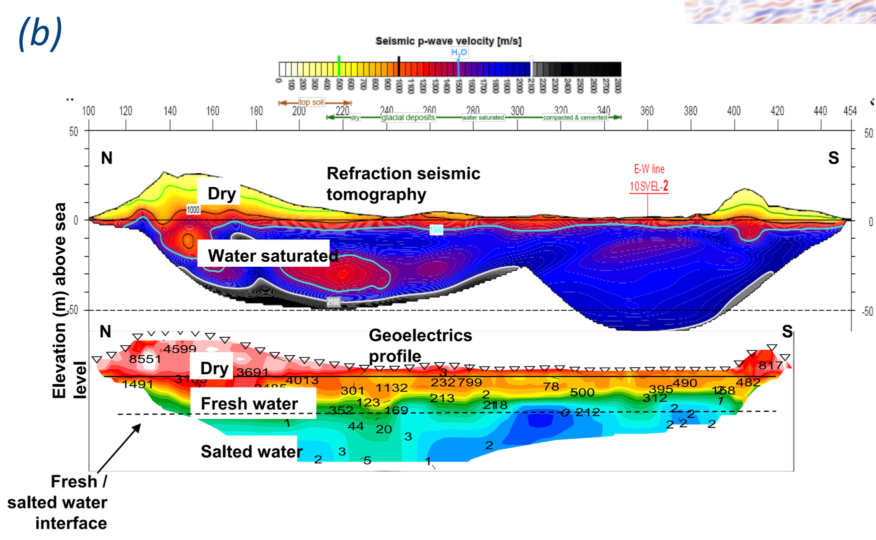


Figure 5: Geomodel building by integration and joined interpretation of various datasets. (a) Completion log; (b) Vp model from refraction seismic tomography and resistivity model from geoelectric profiling along the same 2D N-S line as for the shown seismic in c; (c) Snapshot of the deep geomodel. Seismic interpretation is done on the depth migrated images of Figure 4b. The interval velocity model is the result of the combination of the interval velocities at depth from FWI (Figure 4a) and the formation velocities from well logging correlated to the VSP profile.

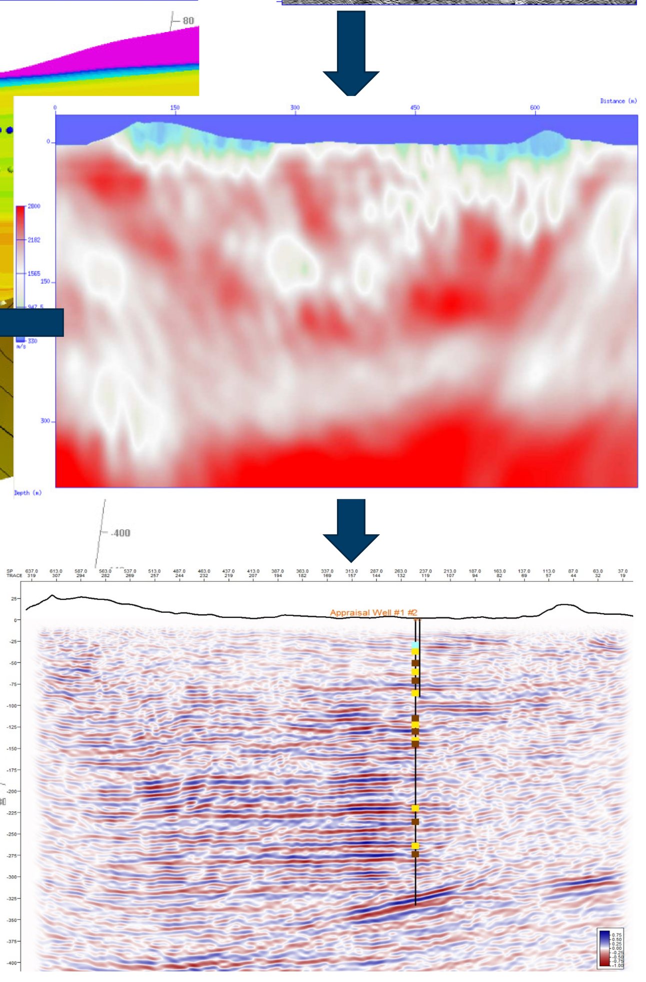
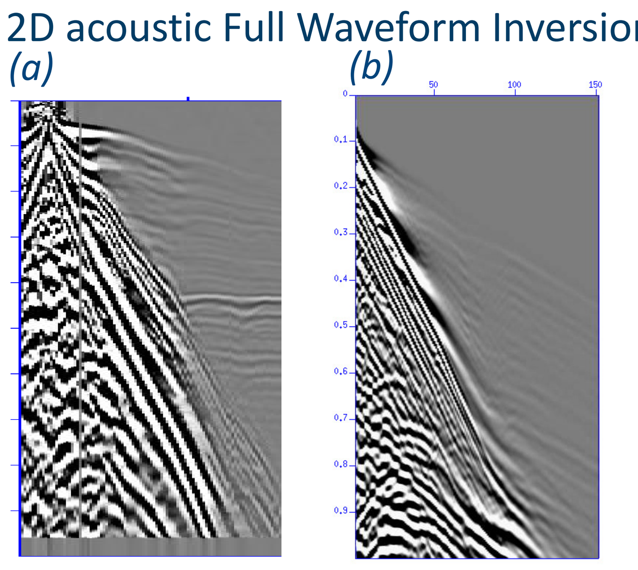


Figure 4: (a) Vp velocity model obtained by applying Full Waveform Inversion (FWI) to the seismic data; (b) Slip-step post stack depth migration of the re-processed data of Figure 3b. Constant velocity for the stack has been used. The migration is performed with a smoothed version of the FWI model

Sensitivity of surface seismic monitoring

Testing performed using:

- Elastic properties derived from CO2 injection simulations (Figure 7)
- 3D acoustic and elastic seismic modelling in time domain (TIGER) (Figure 6);
- 2D acoustic Full Waveform Inversion (FWI) evaluated for improved plume resolution



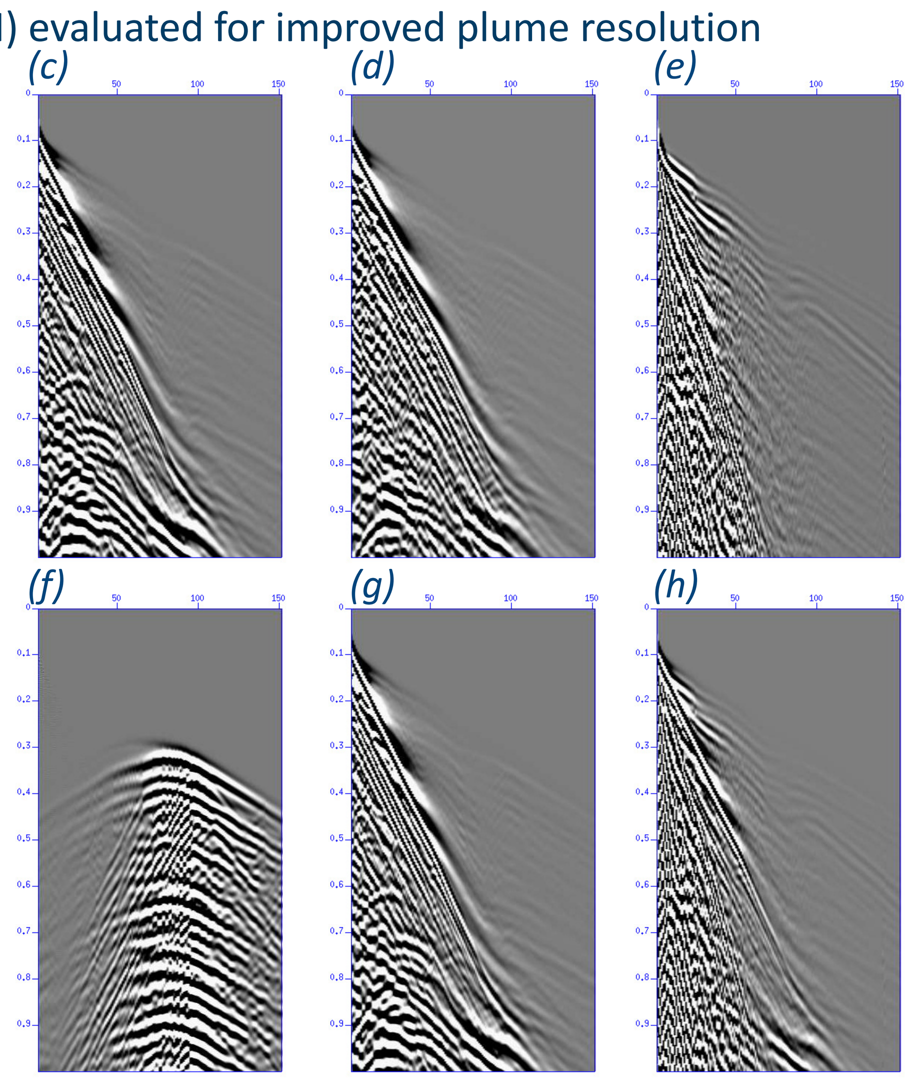


Figure 6: Seismic modelling: (a) example of real shot gather, raw ; example of shot gathers obtained for: (b) acoustic case without plume or diffractors ,(c) acoustic with plume and no diffractors,(d) acoustic with plume and diffractors,(e) elastic case with plume and diffractors; (f), (g), and (h) are the differences between (b) and (c), (d), (e) respectively. Even though the elastic modelling seems very sensitive to the presence of diffractors, the generated synthetic shot reproduces accurately the real shot gather (a)

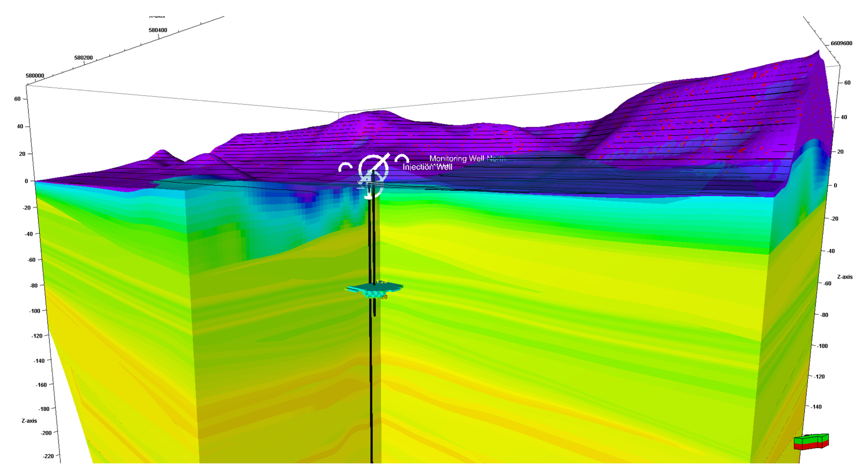


Figure 7: Vp velocity model corresponding to the case of CO_2 injection in the complex model of figure 5. Topography, weathered layer, near surface diffractors and realistic geology are implemented

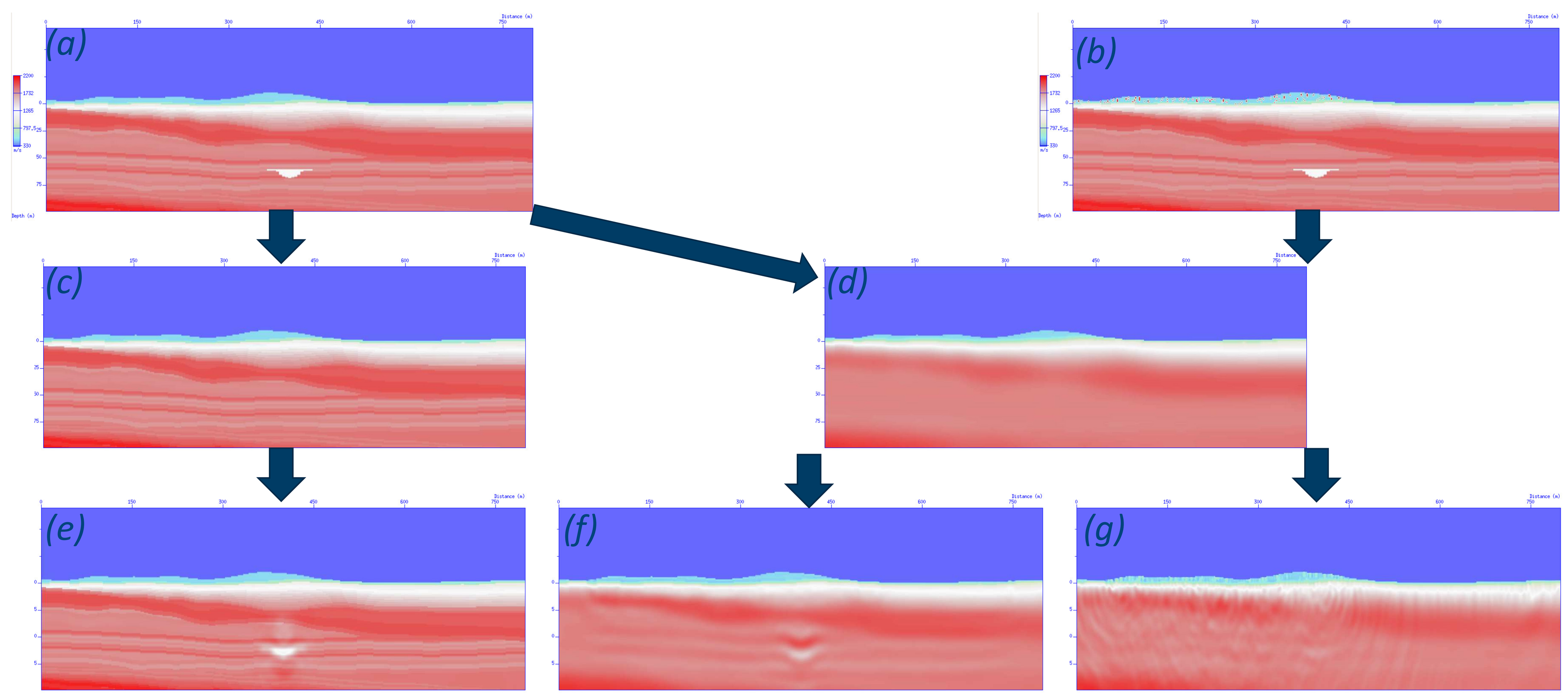


Figure 8: Seismic inversion results using acoustic FWI: (a) and (b): True P-wave models with and without diffractors in the weathered layer; (c) and (d): initial velocity models for the inversions; (e) (f) (g): inversion results

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