GRUPPO NAZIONALE DI GEOFISICA DELLA TERRA SOLIDA

35° CONVEGNO NAZIONALE

RIASSUNTI ESTESI DELLE COMUNICAZIONI

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CASTELLO CARLO V

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EXPERIENCE OF ACOUSTIC FWI ON SEISMIC LAND DATA

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Introduction. After more then ten years of research and development, Full Waveform Inversion (FWI) still remains challenging and even now there are many topics that are open to debate. The solution of the inverse problem, the limitation of the computational costs and the estimation of a good initial models from where to start the inversion, are just some of these topics. On the other hand, FWI applicability and success is also very dependent on the characteristics of the input seismic data and in particular: the signal-to-noise ratio, the maximum recorded offset and the low frequency content. For this reasons, actual and successful examples found in the literature mainly refer to marine seismic applications (Sirgue *et al*., 2010, Guasch *et al*., 2015), while limited experiences refer to land data FWI (Brossier *et al*., 2009, Plessix *et al*., 2010, Al-Yaqoobi *et al*., 2013, Galuzzi *et al*., 2016). This is mainly due to the generally poor quality of the gathers recorded onshore, but also to the difficulty on the choice and estimation of the source wavelet from the actual data and finally to the topography and near surface effects that alter and contaminate with noise the gathers. Indeed, if the kinematic of the events is the main information that we want to invert, as it is discussed here, processing can be useful to partially circumvent this limitations and to recover the coherency of the events without taking into account the amplitude and phase behaviours. In this work, we present an experience of acoustic genetic algorithm (GA) driven FWI on a 2D seismic line acquired onshore, in the South Tuscany, aimed at estimating a low-frequency low-wavenumber P-wave velocity model, that could be used as starting model for a subsequent gradient based FWI. In the first part of this work, we discuss the processing steps applied to improve the signal-to-noise ratio of the gathers and finally to generate the observed data. In the second part, we describe the stochastic FWI employed that makes use of a two-grid approach, a coarse grid for the inversion and a fine grid for the modeling and the GA as the inversion engine. This methodology is discussed in Sajeva *et al*. (2014) and in Tognarelli *et al*. (2015) where is applied on synthetic and field marine data.

Seismic data. The data used in this work pertain to the CROP18a line (Scrocca *et al*., 2003), acquired in the CROP Project framework. They are composed of 195 shots with maximum

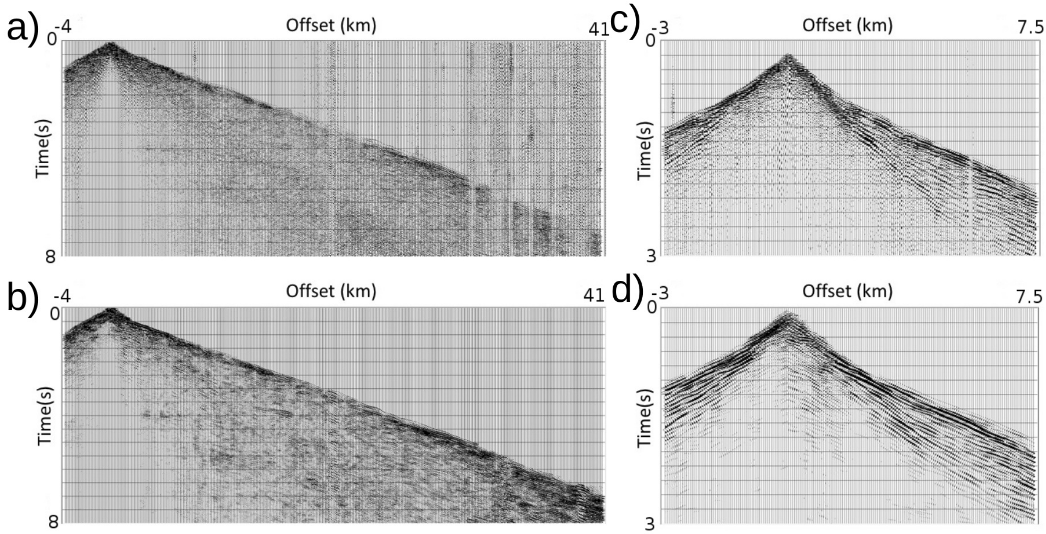

Fig. 1 – a) raw expanding spread experiment; b) same expanding spread experiment of a), after the processing;c) raw shot gather;d) same of c), after the processing.

recorded offset of 7.5 km and two expanding spread experiments, located at the beginning and at the end of the profile, respectively, that are characterized by a maximum recorded offset of 40 km approximately. The expanding spreads experiments are composite shots where the charge size increases with the source-spread distance to preserve an appropriate signal-to-noise-ratio at far offsets (Stucchi *et al.*, 2003). The total length of the studied profile is around 50 km and the station elevation ranges between 50 m and 450 m. The receiver interval is 60 m, the sample interval is 2 ms and the record length used is 8 s. In Fig. 1a and Fig. 1b is illustrated one of the long-offset experiments before and after the data enhancement. Figs. 1c and Fig. 1d show an example of raw production shot gather before and after the application of the same steps for data enhancement of Fig. 1b. The gathers in Figs. 1b and 1d are obtained after a processing sequence that include trace muting, F-K filtering, F-X deconvolution and dip scan filtering. The observed data employed in the following FWI are the envelope of the low pass filtered (10 Hz) version of the direct and diving waves.

Stochastic full waveform inversion. In the contest of FWI, the numerical solution of the wave equation is required to obtain the predicted data to compare with the observed data. Since we want to model only the direct and diving waves, we use an explicit, 2nd order in time, finite difference algorithm to solve the 2D acoustic wave equation. The model size is approximately 50 km in the length and 4.5 km in depth. The modeling grid is made by 150 x 1563 (Fig. 2a) nodes with a uniform space sampling of 30 m. Because of numerical stability, we consider a time sampling of 2ms, and due to numerical dispersion, the algorithm models correctly the predicted seismograms only in the frequency range up to 10 Hz. The source wavelet is estimated from the data by means of singular value decomposition.

As described in Sajeva *et al.* (2014) and Tognarelli *et al.* (2015), in our inversion approach we use a coarse grid that differs from the modelling grid and that is characterized by a non uniform cell size. A bilinear interpolation is applied to bring the velocity model from the inversion grid to the modelling grid. In order to reduce the number of unknowns for the inversion problem, we decrease the number of nodes as a function of the depth, where the illumination is poorer. The whole procedure allows to reduce the total number of unknowns to 120 (red dots in Fig. 2a).

The GA parameters are set as follow: 300 individuals that evolve for 300 generations, selection rate 0.8 and mutation rate 0.008. The search ranges

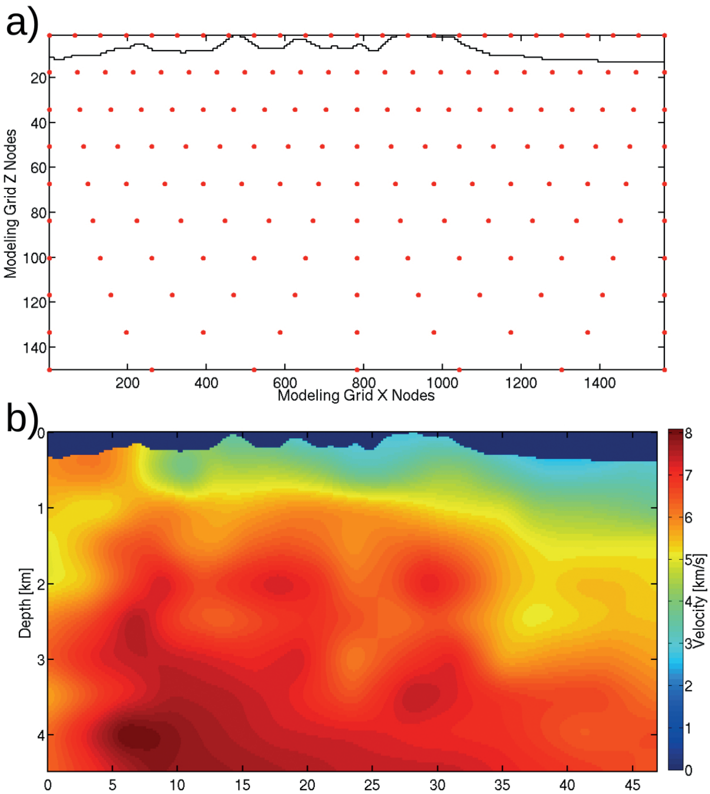

Fig. 2 – a) The axis of the plot represent the number of nodes of the modeling grid. The red dots are the nodes considered in the inversion grid. On top, the black line refers to the topography; b) final velocity model obtained after 300 generations. The model is shown in the modeling grid.

vary from 2000 m/s to 6000 m/s close to the surface and from 4000 m/s to 8000 m/s at the end of the model. In the centre of the model the ranges are linearly interpolated.

As the misfit function, we used the L^2 norm between the observed and the predicted data at the end of the following steps of processing. At first the data are filtered in the same frequency band (from 0 to 10 Hz). Then we compute the envelope in the offset-time window enclosing only the direct and diving wave arrivals and finally carry out a trace by trace normalization.

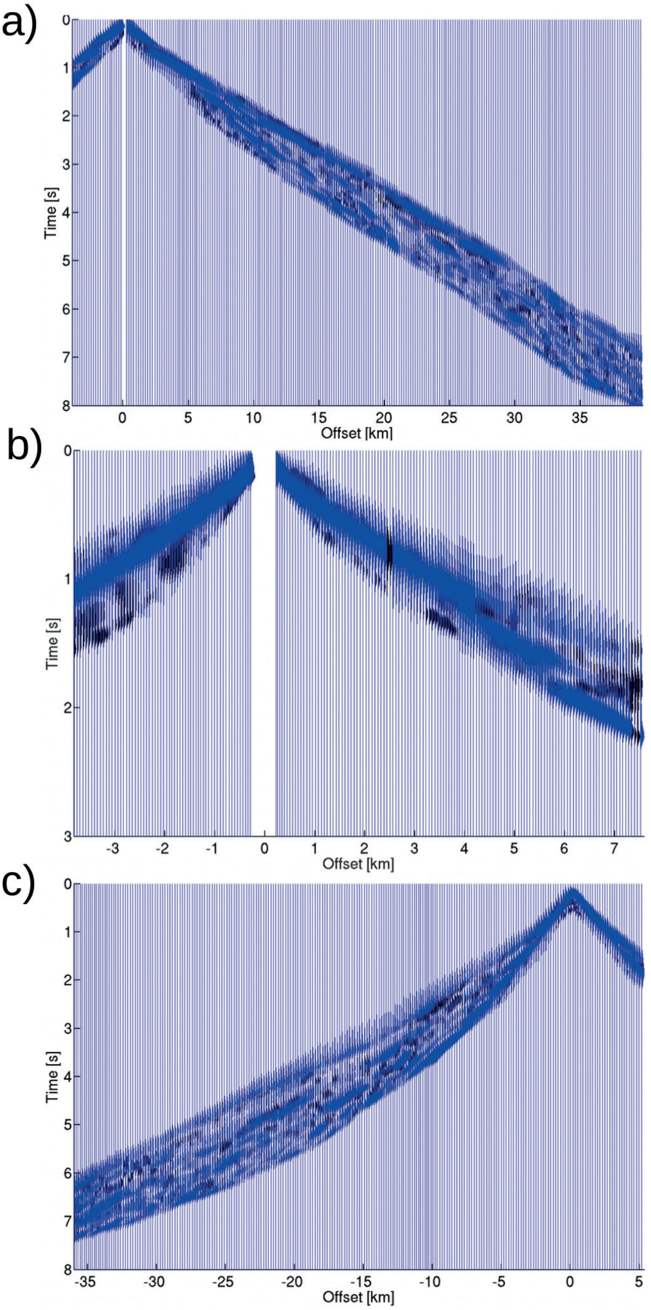

Fig. 3 – Comparison between observed (black) and predicted (blue) data for a) forward expanding spread experiment; b) a production shot located in the middle of the seismic line; c) backward expanding spread experiment.

Results. In Fig. 2b is shown the final velocity model estimated after the 300 generation. Note on the top the topography. Below, the velocity increases in depth and range between 3000 m/s and more than 6000 m/s approximately. Also, the model highlight some features that are in agreement with the geological setting of the area (Scrocca *et al.*, 2003). The most evident is the important velocity contrast that delineates the structure that dip to the right part of the model. In Fig. 3 the observed data (in black) and the predicted data (in blue) are compared for the two expanding spread experiments and for a production shot. As can be noted, the matching between the envelope of the waveforms is satisfactory, increasing our confidence in the obtained result.

Conclusions. In this work we have described the acoustic FWI experience made on a 2D seismic land data. A particular type of evolutionary algorithms (the genetic algorithms) is used in order to reduce the risk of getting trapped into local minima, and the two grid approach is adopted to reduce the computational costs. In order to obtain the observed data characterised by an improved signal-to-noise-ratio where the velocity information of the refracted and diving waves is preserved, we employ a processing sequence that include multichannel filtering and dedicated coherency enhancement operators. The wavelet used in the finite-difference modeling is estimated from the data and to relax the assumption on the phase of the wavelet we adopt the envelope of the observed and predicted data in the misfit computation. The main result obtained consists in a velocity increase at a depth of about 1 km that slightly deepens moving to the right of the profile (North) in agreement with the geological setting of the area. Ongoing works are focused on the estimation of a velocity model by means of travel time tomography to be compared with the model obtained from the FWI. Future works include the possibility to use this final model as a starting point for a subsequent local FWI.

References

Al-Yaqoobi A. and Warner M.; 2013: Full waveform inversion – dealing with limitations of 3D onshore seismic data. *83th Annual international Meeting, SEG*, Expanded Abstract.

Brossier R., Operto S. and Virieux J.; 2009: Seismic imaging of complex onshore structures by 2D elastic frequency-domain full-waveform inversion. *Geophysics*, **74**, no.6, WCC105–WCC118.

Galuzzi B., Tognarelli A., Stucchi E. and Mazzotti A.; 2016: Stochastic FWI on wide-angle land data with different order of approximation of the 2D acoustic wave equation. 78th Conference & Exhibition, EAGE, Expanded Abstract.

Guasch L., Burgess T. and Warner M.; 2015: Optimised adaptive waveform inversion - improved convergence via conjugate gradients and superior step-length calculation. 77th Conference & Exhibition, EAGE, Expanded Abstract.

Plessix R. E., Baeten G., de Maag J. W., Klaassen M., Rujie Z. and Zhifei T.; 2010: Application of acoustic full waveform inversion to a low-frequency large-offset land data set. *80th Annual international Meeting, SEG,* Expanded Abstract.

Sajeva A., Bienati N., Aleardi M., Stucchi E. and Mazzotti A.; 2014a: Estimation of velocity macro-models using stochastic full-waveform inversion. *84th Annual international Meeting, SEG*, Expanded Abstract.

Scrocca D., Doglioni C., Innocenti F., Manetti P., Mazzotti A., Bertelli L., Burbi L. and D'Offizi S.; 2003: CROP ATLAS: seismic reflection profiles of the Italian crust. Memorie Descrittive della Carta Geologica d'Italia 62, 15–46.

Sirgue L., Barkved O.I., Dellinger J., Etgen J., Albertin U. and Kommedal J.H.; 2010: Full waveform inversion: The next leap forward in imaging at Valhall. *First Break*, **28**, 65–70.

Stucchi E., Zanzi L. and Mazzotti A.; 2003: Lessons learned from the acquisition and processing of the CROP C-ALPS/b, CROP 03, CROP 04, CROP 18 NVR and expanding spread seismic data. *Memorie Descrittive Carta Geologica d'Italia.*, **62**, 75-88.

Tognarelli A., Stucchi E., Bienati N., Sajeva A., Aleardi M. and Mazzotti A.; 2015 Two-grid stochastic full waveform inversion of 2D marine seismic data. 77th *Conference & Exhibition, EAGE*, Expanded Abstract.