Final project report

Project ID **2002/3.3**
Title **RADA** (Reprocessing Avanzato di Dati sismici Antartici)

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Assigned funding 46481,12 Euro

Activities and results (max 3000 characters)

The main objective of this research is to demonstrate the potential of scientific innovation that can result from the re-processing of seismic data in the light of new technologies made available recently. Two scenarios have been devised that will test this hypothesis in different contexts and problems.

In the first case we analyzed the Magallanes-Fagnano fault system, a transcurrent margin in the region of Tierra del Fuego (the very tip of South America) which defines a long segment of the boundary between the Scotia and South American plate, extending far west of the Strait of Magellan to the Atlantic offshore, essentially dividing the island (Tierra del Fuego) in two continental blocks. In many other strike-slip environments developed on continental crust, such as the Dead Sea rift, or the San Andreas fault, pull-apart basins systems may be recognized. In these cases, the seismic profiles show asymmetric basins limited by nearly vertical discontinuities on one side (the transcurrent segment), and a set of normal faults subsidiary on the other side. This complex configuration can reflect different tectonic mechanisms, in which orthogonal extensional periods have alternated with oblique extensional periods. Unfortunately, the seismic sections processed in the past do not return the necessary details to this type of reconstruction.

The second area considered, namely the Pacific margin of the Antarctic Peninsula, is composed of depositional lobes with major glacial surfaces of erosion on the platform and sediment drifts characterized by continuous deposition on the continental rise. The transfer of sediment from the continental platform to the rise takes place through small gullies. On the drifts, sediments are well laminated with high frequencies. We have detected the presence of a transparent body related to a debris flows from the slope. Unfortunately, the correlation between drift sequences on the continental rise and other facies on the platform is difficult because of the lack of continuity and the low signal to noise ratio of the data on the continental slope.

In the first phase of the project a lot of energy was spent gathering all the papers and documentation in general available on the study areas in order to focus on a relevant subset of seismic lines. In collaboration with the analysts responsible for the original processing, problems were highlighted that could not be solved with the techniques available at those times.

Much effort has been invested in testing techniques for noise reduction. Good results were obtained in the band of the useful signal, the most problematic, using techniques of spectral shaping. These use a median filter which eliminates the peaks in the frequency spectrum associated with the noise while keeping intact the signal (Figure 1).

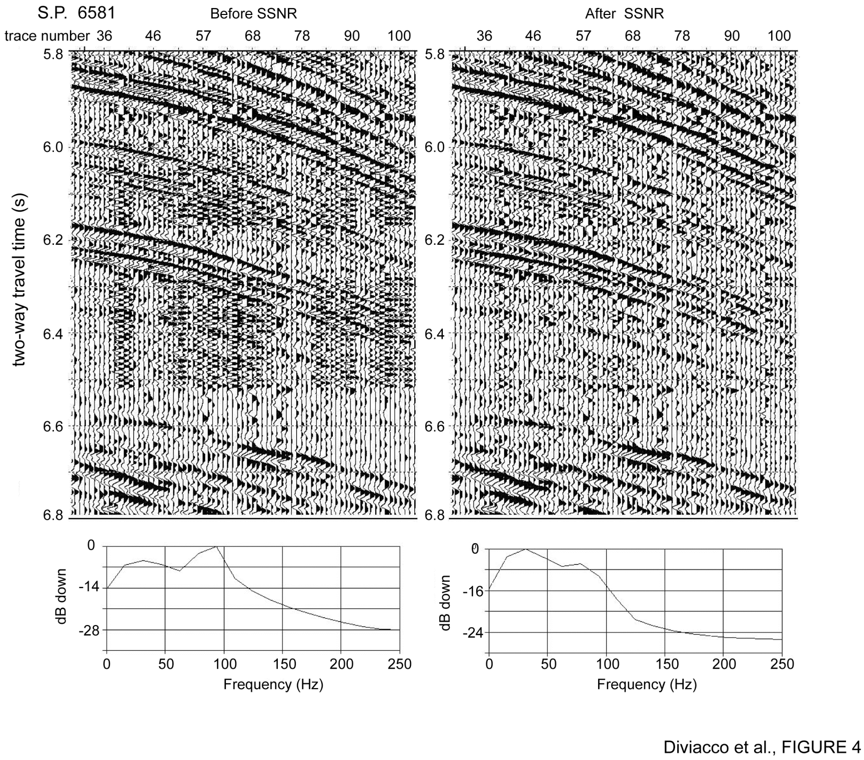

Figure 1 Noise reduction by spectral shaping

Once a good S / N ratio data are made available, these can be can deconvolved. Conventional techniques are based on a large number of assumptions which are rarely met in case of complex structures corresponding to the real situation, which gives generally insufficient results. Another approach that may give better results is the one that involves the preparation of a deconvolution operator using the Hilbert transform and the autocorrelation (Figure 2).

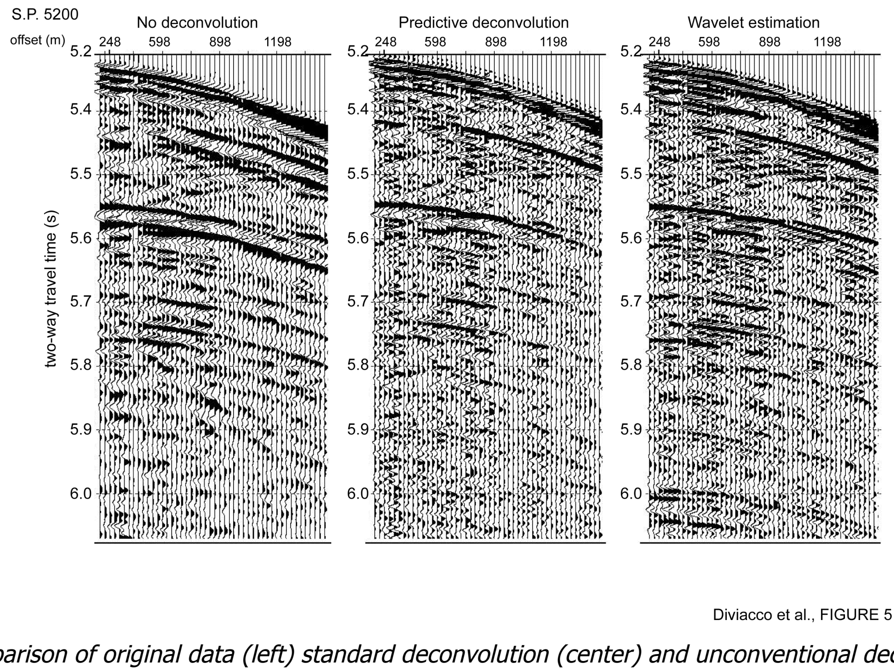

Figure 2 Comparison of original data (left) standard deconvolution (center) and unconventional deconvolution (right)

This method is less sensitive to the problems of truncation and assumptions such as randomness of reflectivity. The results obtained using this method were, in fact, good in all the examined cases (Figure 3). The provision of good quality data can be avoided in successive stages of unwanted migration signals propagate along the migration hyperbole. At the same time, unfortunately, the work demonstrated that the techniques for multiple removal yield results that vary widely depending on the individual situation analyzed.

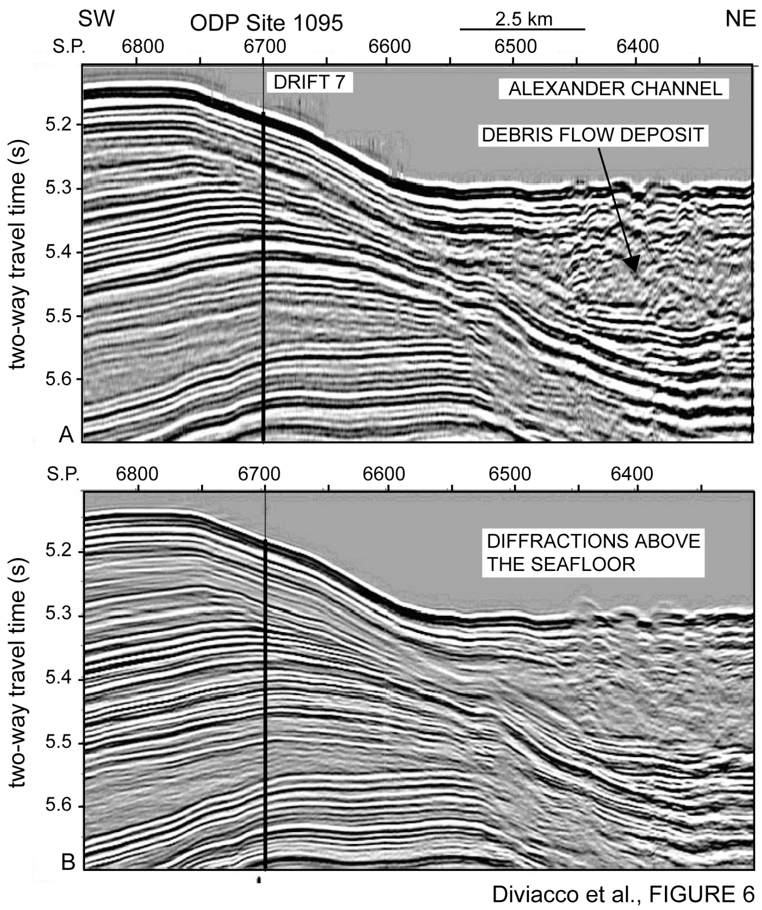

Figura 3 Comparison of original (upper) and represcessed (lower) seismic sections

Different filtering techniques have been used from traditional domains as Fk to the more advanced Tau Pi or radon. We realized that specially in the Magallanes-Fagnano fault zone the primary signal system is still disturbed.

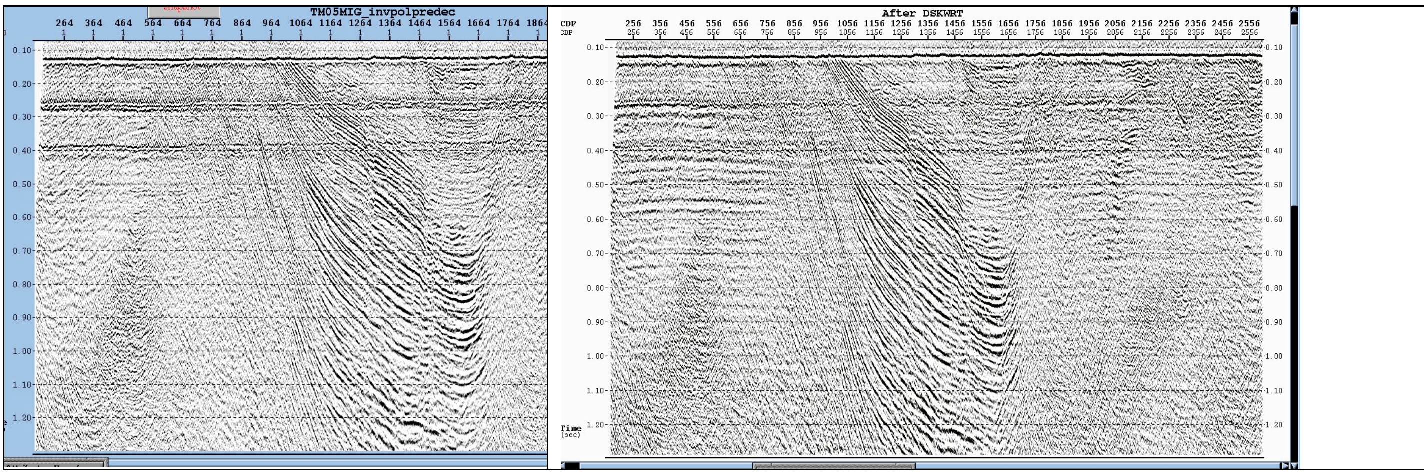

Figura 4 (left) Comparison between original seismic section after a time migration and the reprocessed and time migrated version (right)

The sea floor is shallow and does not allow a safe discrimination based on speed while heavy interventions cause deterioration of the useful signal. Despite these limitations, especially in later steps of migration, that relocate possibly dispersed energy, it is possible to get improved results (Figure 4).
In both test-beds it is possible to identify complex geometries with horizontal variations of seismic waves propagation velocity. In the Magallanes-Fagnano fault zone, this is due to tectonic factors. In the Antarctic Peninsula this is due to variation in the lateral facies complicated by the presence of the continental slope, where the velocity difference between the water-layer and sediments adjacent leads to distortions in the buried structures. In fact in these cases the traditional concept of Common Mid-Point (CMP) loses its meaning so that the classical techniques of imaging in time are no longer able to reconstruct the correct position of the reflectors. Here, Depth-imaging techniques that can reconstruct the velocity field and define the correct position of the reflectors should be used. Data processing in these cases usually diverge from the standard path, needing often to loop to include the results obtained in subsequent steps. This is the case for example of amplitudes recovery that need to be reconstructed in successive iterations after a velocity model is defined.
The technique that gave the best results in defining the interval velocity models to be used in depth migration was that of coherence-inversion. Here, we start from the horizon in the un-migrated section, and convert it in depth using test velocities. Then time horizons are generated from this model to see the coherence with the original time horizon, and pick the velocity that minimize incoherence The velocity analysis does not assume the hyperbolic moveout since they are computed ray tracing through the model.
Consistency inversion avoids high-frequency variations as they may generate events that are not real. In practice this means defining smoothed velocity models. If this is generally a limit, it may be used in the presence of specific geometries such as pull-ups that remain after the migration allowing to highlight the presence of small velocity anomalies that can be

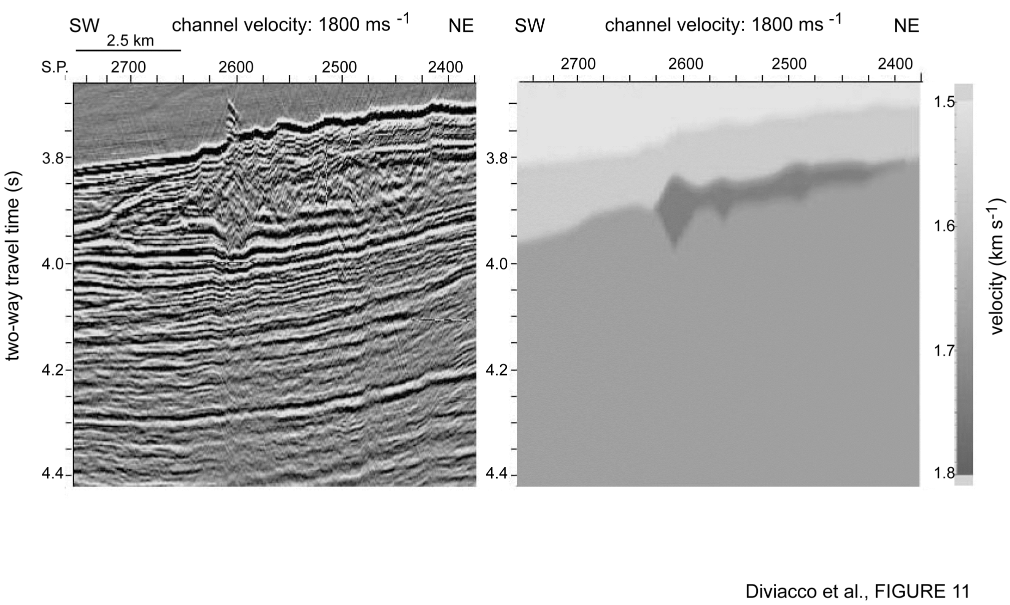

Figura 5 Depth migrated seismic section (left) and its velocity model defind via coherency inversion (right)

After having established the most suitable procedures to solve the various problems found in the two test-beds, we continued processing a certain number of seismic sections to understand the advantages gained in terms of interpretation.

In the case of the Tierra del Fuego area, several seismic lines acquired in previous PNRA projects (TESAC, SCAPPAM-II, Sanskrit) have been reprocessed obtaining sections that shows an improved data quality. This allowed an easier interpretation and mapping of the tectonic features of the area and to highlight the peculiarities of the area especially in comparison with the western Scotia Sea (Sauli, Lodolo et al., 2004).
In the case of the Antarctic Peninsula, the reprocessed seismic sections allowed the identification of a seismically transparent body of considerable size (1800 km3), interpreted as debris flow buried by distal turbidites, which can be considered unique in the depositional history of the Antarctic Peninsula Pacific margin. The quality of the reprocessed data allowed to follow the horizons that define this body and correlate it with sites 1096 and 1095 of the Ocean Drilling Program (ODP) so that the body can be dated to the late Pliocene (Diviacco, Rebesco, Camerlenghi 2006) .
Summing up, the RADA project has demonstrated that the new processing techniques made available recently, allow achieving clear improvements on seismic data acquired in the past. The improvements are possible both in vertical resolution (through wavelet estimation) and in spatial resolution (through migration). In terms of noise reduction, while good results are obtained to remove instrumental noise or random, some difficulty remains in removing multiples, especially in the case of shallow water.

Products

A – papers in scientific magazines

- *P. Diviacco, M. Rebesco, and A. Camerlenghi* 2006 "Late Pliocene mega debris flow deposit and related fluid escapes identified on the Antarctic continental margin by seismic reflection data analysis", Marine Geophysical Researches, Volume 27
- *C. Sauli, E. Lodolo, N. Wardell, A. Tassone, & A. Polonia. 2004*. Seismic expression of the Western Scotia Sea continental margin. Bollettino di Geofisica teorica ed applicata. Vol. 45. Nro. 2 suplement. GeoSur 2004: 162.

B – book chapters

C - proceedings of international conferences

- *Diviacco, P., Camerlenghi, A.* 2005,"Late Pliocene mega debris flow deposit and related fluid escapes identified on the Antarctic Peninsula continental margin by seismic reflection data analysis",. International Conference on Submarine Mass Movements and Their Consequences" IAS conference,Aberystwyth
- *L.Desanti, Diviacco, P. et al*, 2004, "Icesheet load, erosio and deposition effects on sedimentation: a geophysiscal and geological approach", Frontiers and opportunities in antarctic geosciences August 29-31, 2004, Certosa di Pontignano (Siena).
- *F.Donda, Diviacco P. et al,* 2006,"Debris flows in Antarctica: where? when? why?" EGU 2006
- *P.Diviacco, M.Rebesco, A.Camerlenghi & N. Wardell.* 2003," Advancement in understanding the sedimentary process of the Antarctic Peninsula margin from re-processing of formerly collected data." 9th International Symposium on Antarctic Earth Sciences, ISAES Potsdam, Germany.

D – proceedings of national meetings and conferences

- *Rebesco, M., Diviacco, P., Camerlenghi, A., Geletti R., Canals, M* "Late Pliocene margin development and mega debris flow deposits on the Antarctic Peninsula continental margin" Geoitalia,Spoleto 2005
- *L.Desanti, Diviacco, P. et al*, 2004, "Icesheet load, erosio and deposition effects on sedimentation: a geophysiscal and geological approach", Frontiers and opportunities in antarctic geosciences August 29-31, 2004, Certosa di Pontignano (Siena).

E – thematic maps

F – patents, prototypes and data bases

G – exhibits, organization of conferences, editing and similar

H - formation (PhD thesis, research fellowships, etc.)

Research units

Paolo Diviacco (principal Investigator)
Michele Rebesco (Pacific margin of the Antarctic Peninsula)
Emanuele Lodolo (Magallanes-Fagnano fault system)
Chiara Sauli (processing)

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Notes a final report on the Rada project has alredy been transmitted in march 2008