P. GALUPPO and R. GELETTI

SEISMIC SIGNAL ENHANCEMENT OF ANTARCTIC CRUSTAL DATA

Abstract. Most of the seismic data acquired in the Ross Sea (Antarctica) are affected by a severe reverberation problem. The strongest reverberation energy comes from sea-bottom related multiple reflections. A simple CMP (Common Mid Point) stack-based processing is not sufficient to overcome this problem. This is particularly true if the objective is deep reflectors. Therefore a reprocessing of some of the seismic line was done using specific, and in one case innovative, procedures. The weighted stack approach was not effective, at least in the case of line IT89A25. Application of the *f-k* domain multiple suppression method gave evidence of a deep reflection previously masked. The best result, however, came from the application of a newly implemented multiple suppression algorithm; reflections, in general, and in particular those associated with the acoustic basement and the Moho discontinuity were considerably improved.

INTRODUCTION

The seismic data acquisition campaigns conducted between 1987 and 1991 as part of the National Research Program in Antarctica produced a total of 21,490 Km of seismic lines. Most of the data is affected by strong coherent and random noise. Particularly relevant is the sea-bottom multiple reflection. This severe reverberation is very common in Antarctic continental shelf data. Sea-bottom multiples seem mainly due to overcompaction, and the consequent seismic velocity increase, of the near surface sediments, resulting from loading of the shelf by grounded ice (Larter et al., 1990). Standard processing is not very effective for this problem, especially when primary events have small amplitude compared with that of the multiple. Furthermore, deep reflectors are often either interfered by many high order multiples or completely obscured by them.

SPECIFIC SEISMIC PROCESSING PERFORMED

The reverberation noise is the main factor in the poor quality of most of the seismic data recorded in the Ross Sea area. In many cases the standard processing sequence is not able to reject or sufficiently attenuate this choerent noise without affecting useful signals.

When the target is the events associated with deep reflectors (e.g. the crust-mantle interface), particular care is required if strong multiple reflections are present, because primary reflections recorded at large two-way travel times have small amplitude (because of spherical divergence and energy absorption), much lower than that of multiple reflections. Therefore the main danger in multiple removal aimed at deep reflector detection is suppression or distortion of the useful signals.

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Istituto di Geodesia e Geofisica, University of Trieste, via Dell'Università 7, 34123, Trieste, Italy.

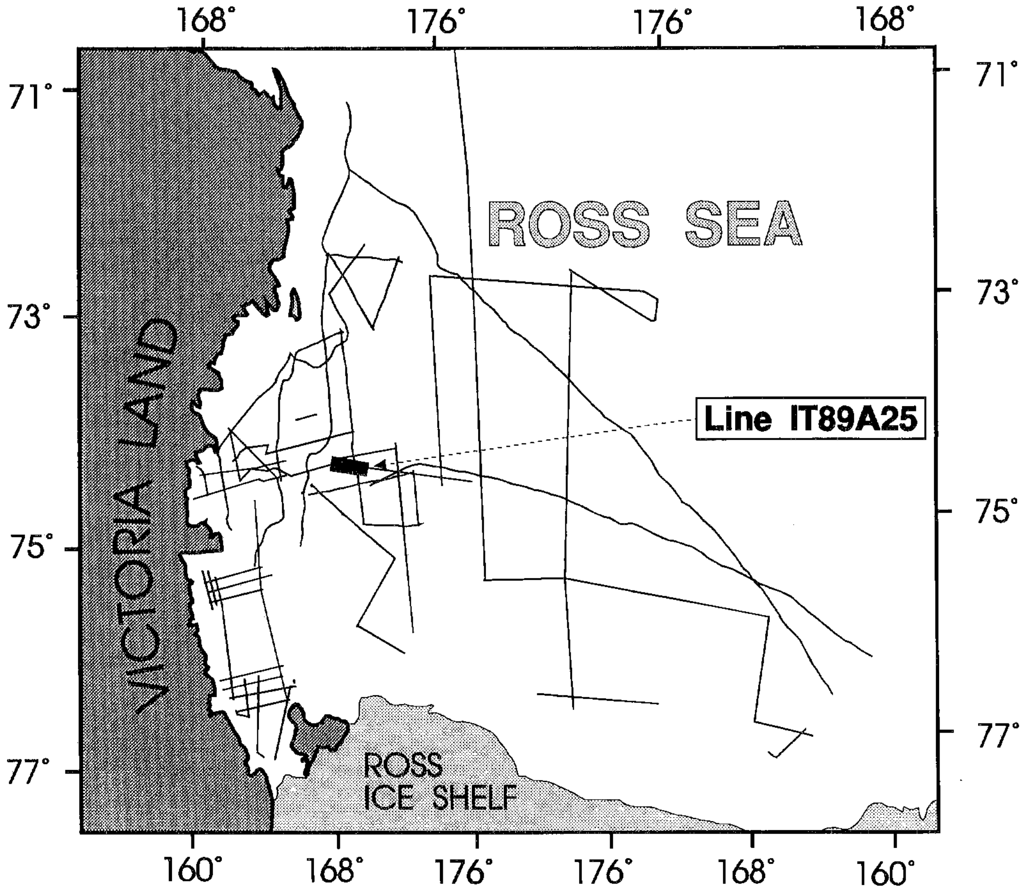

Fig. 1 - Location map of the Italian seismic profiles acquired in the Ross Sea Embayement area between 1987-1990. The segment of line IT89A25 used to illustrate the reprocessing results is evidenced with the black rectangle.

In order to recover some of the information still hidden in the field data, a specific strong reprocessing was attempted. To illustrate the procedures applied and the results obtained, we describe those used for seismic line IT89A25 located on Coulman High (Fig. 1). This line was acquired using a streamer 3000 meters long; the acquisition geometry yielded a 3000% coverage; the sampling rate was 8 ms. Line IT89A25 is characterized by strong multiple reflections that affect the traces down to late arrival times. The field records and a near trace section showed that various kinds of multiples are present, from simple intra-water reverberation to complex interformational reflections and peg-legs.

Conventional processing followed this sequence:

- amplitude recovery
- deconvolution before stack
- preliminary velocity analysis (about 1 analysis every 10 Km)
- normal moveout correction
- weighted stack

The section obtained (Fig. 2) is characterized by a low signal/noise ratio. A careful examination of the section leads to the conclusion that most of the visible events are associated with various-order multiples.

The first attempt to improve the quality of the data was based on the *f-k* domain filtering

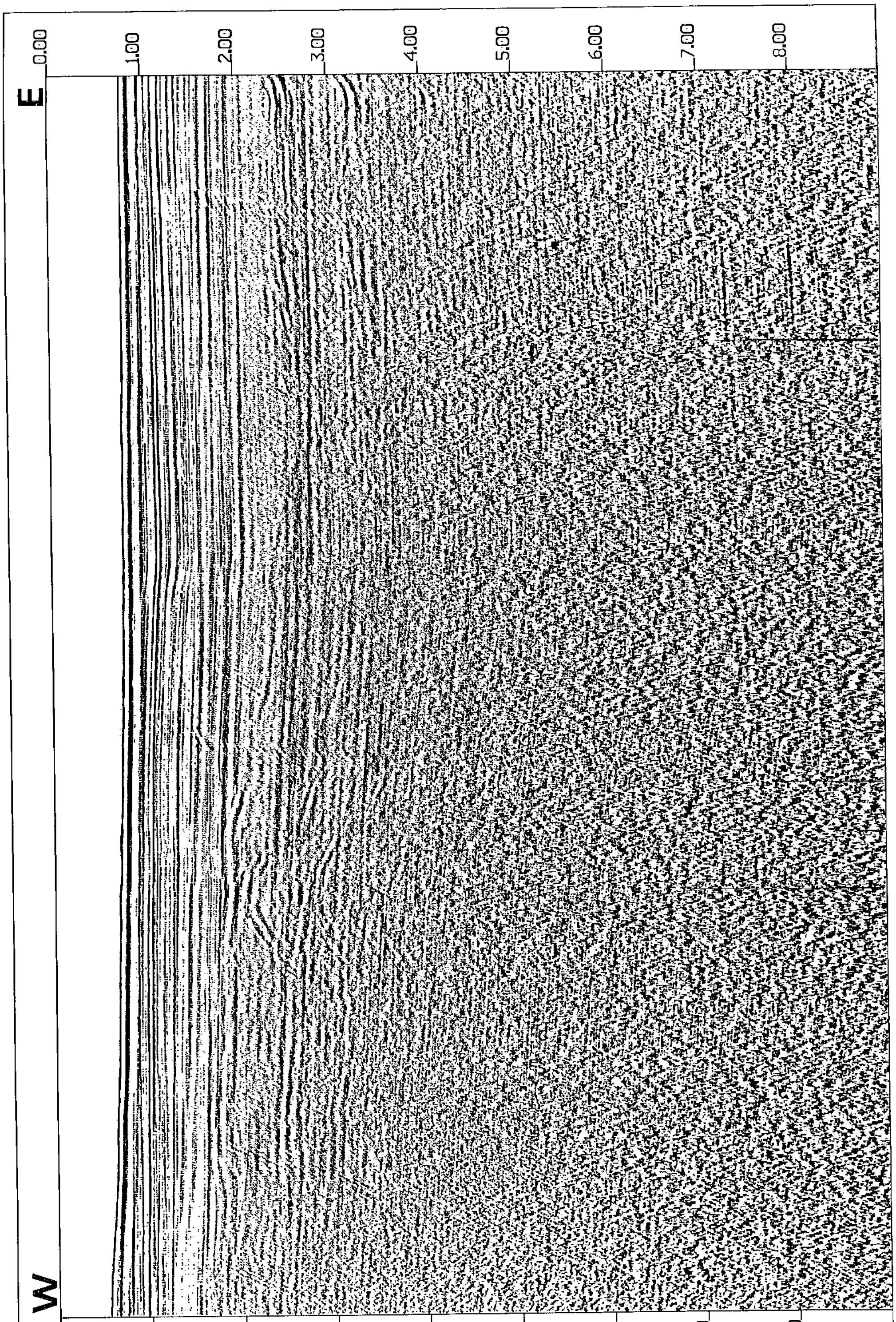

Fig. 2 - Stack section of part of line IT89A25 after a standard processing sequence, including weighted stack.

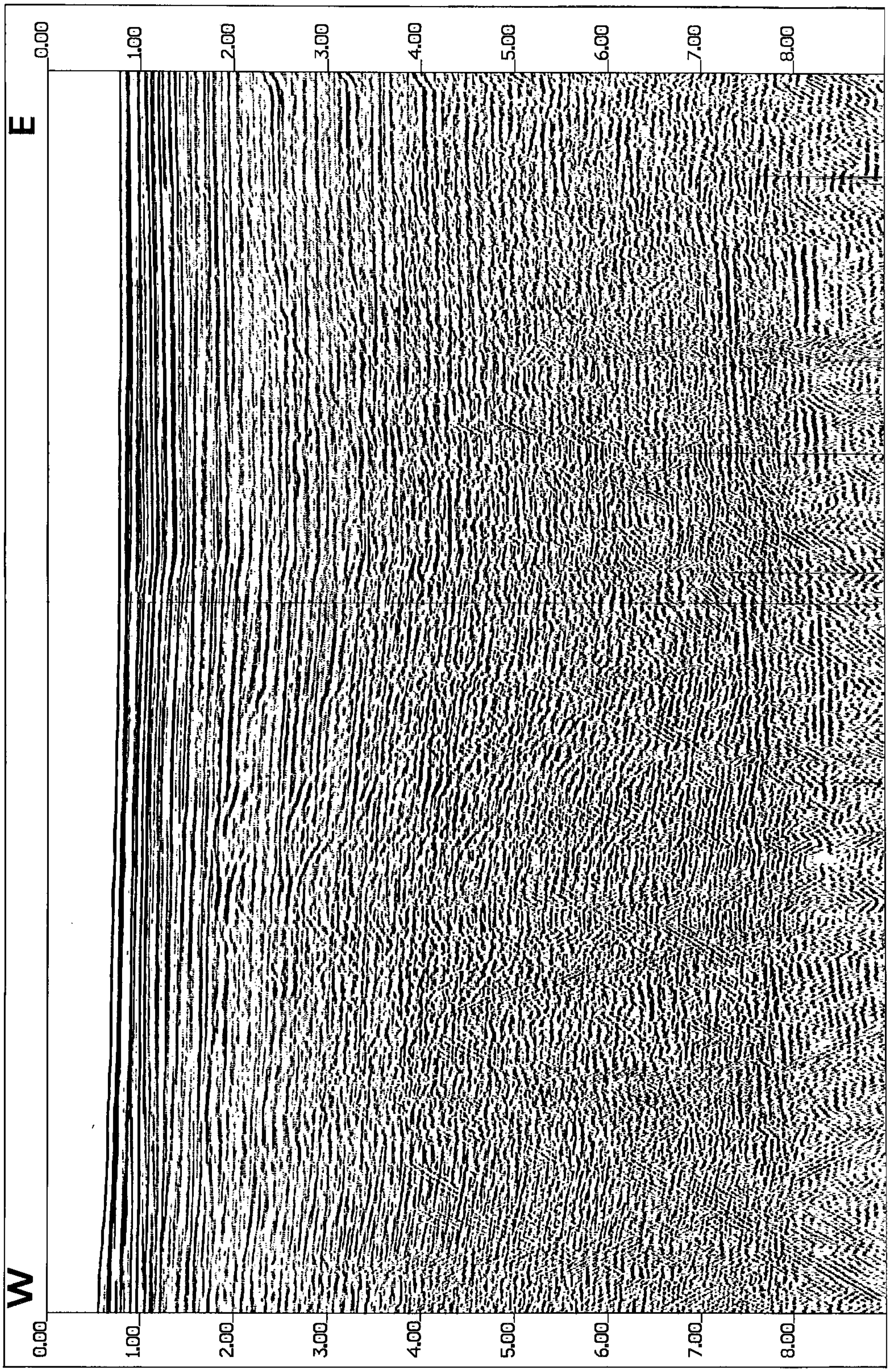

Fig. 3 - Stack section of the same line segment as in Fig. 2 obtained using f-k filtering for multiple attenuation.

approach. This technique was judged to be the most promising in this case, while predictive methods were ignored because contamination by strong random noise has distorted the original shape of the signal and because sea floor multiples are not truly periodic except at very short offsets.

Filtering in the *f-k* domain is commonly used for multiple suppression and can be very powerful when there is large differential moveout (i.e moveout separation in the seismic record between primaries and multiples). Many schemes can be adopted for *f-k* filtering; the two main design aspects are the choice of move-out correction and definition of a rejection area in the *f-k* domain. The various tests conducted suggested to correct the target multiples so that the primaries are overcorrected. Then a rectangular filter centered over the frequency axis in the *f-k* plane is used. The overall processing sequence applied to IT89A25, including *f-k* filtering, is the following:

- amplitude recovery
- prestack deconvolution
- first-order-multiple velocity analysis
- NMO correction using first order multiple velocities
- *f-k* filtering
- first-order multiple NMO removal
- stacking velocity analysis (about 1 every 5 Km)
- NMO correction using stack velocities
- stack
- time-variant frequence filtering
- post stack *fx* deconvolution

The stack section obtained after *f-k* filtering is shown in Fig. 3. This sections exhibits a very clear deep reflector at a time of 7 to 8 seconds, attributable to the Moho discontinuity. The intra-water multiple of this signal, located between 8 and 9 seconds can be regarded as a confirmation of the Moho signal.

Although the multiple reflection coherency has generally been broken up, the section contains some remnant multiple energy, particularly in its shallow part. This energy masks in an unpredictable fashion other important reflectors like the acoustic basement that is partially visible between 2 and 3 seconds. We tried to further reduce the multiple energy by iterating the *f-k* filter with higher order multiple correction and with lower removal threshold. The main drawback was that, along with multiples, primaries were also suppressed or attenuated.

In order to better exploit the large moveout separation between primaries and multiples characterizing the IT89A25 CMP gather data, and to preserve primary energy as much as possible, we developed and tested a new filtering technique aimed at multiple suppression. This technique uses, like *f-k* filtering, the moveout discriminant, but works directly in the time-offset domain. The method is based on a variation of the differential operators used in image processing to locate edges and contours of objects. Obviously, the key characteristic of the algorithm is the elimination from the seismic record of the signals recognized as corresponding to multiples. The most notable advantage of this procedure over the *f-k* technique is its capacity to leave the primary signal component virtually unaltered after suppression of the unwanted interference component. The processing sequence applied, including this innovative multiple suppression technique, is the following:

- amplitude recovery
- first-order-multiple velocity analysis
- NMO correction using first order multiple velocities
- multiple suppression using differential operator
- first-order multiple NMO removal
- stacking velocity analysis (about 1 analysis every 5 Km)

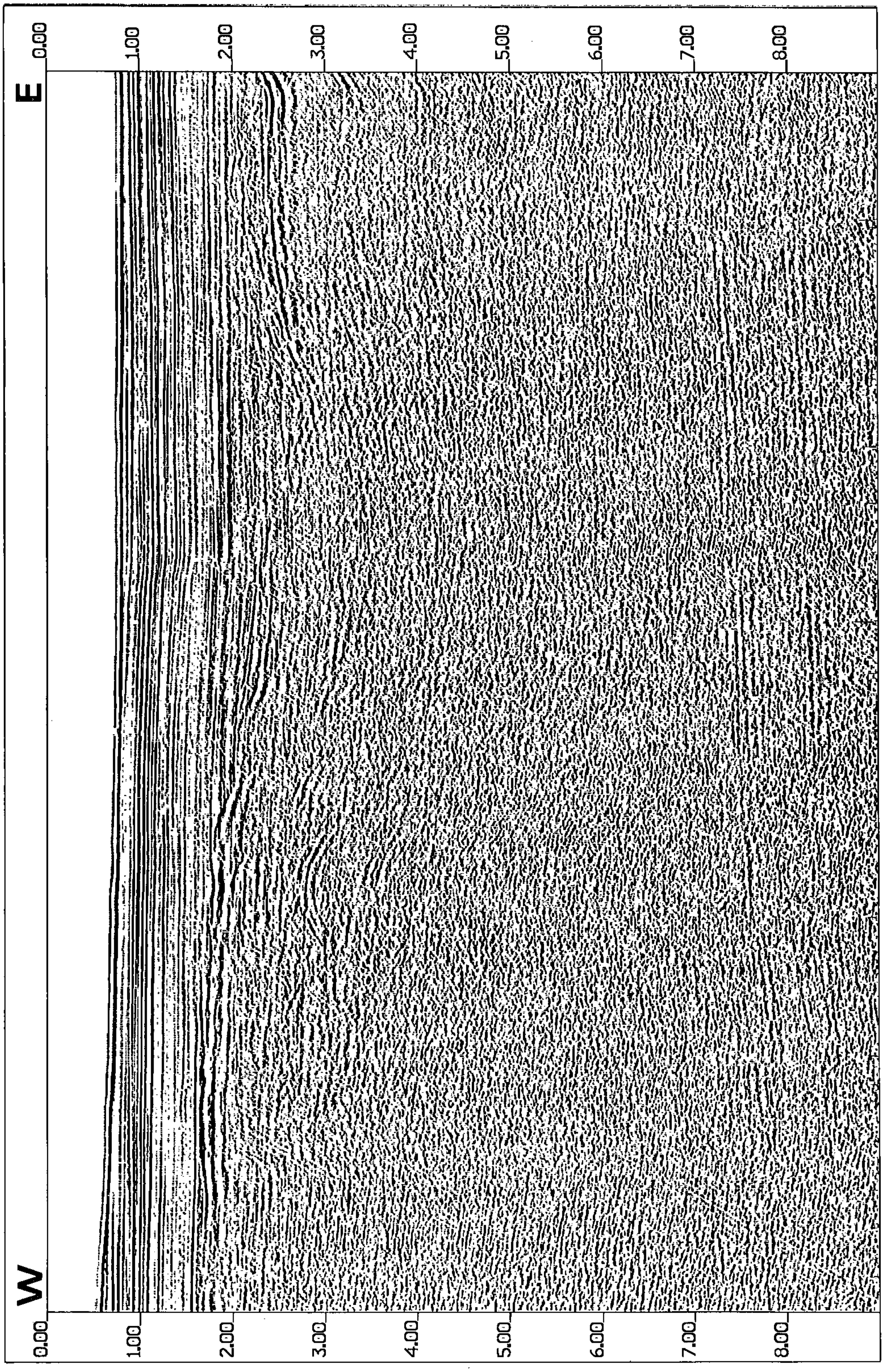

Fig. 4 - Final stack section of the same seismic data as in Figg. 3-4. The considerable multiple attenuation has been achieved by application of our innovative time-offset filtering algorithm.

- NMO correction using stack velocities
- stack

Deconvolutions before or after stack and time-variant filter were left out in order to evidence the effects due to the newly implemented algorithm.

The final stack section obtained (Fig. 4) shows the following interesting results:

- the presence of multiple energy, of whatever kind, has been dramatically reduced (this is particularly relevant since only water-bottom related multiples were addressed);

- the lateral coherency, continuity and discrimination of the deep reflection has been considerably improved;

- the acoustic basement reflection can be clearly identified continuosly, along the entire section (between 2 and 3 seconds).

One additional aspect is that in the zone between the acoustic basement and the deep reflectors there are no more strong multiples.

Careful stacking velocity analysis of the above described main reflectors confirms that these are primary events.

CONCLUSION

From the results obtained, the following processing techniques effectively contributed to multiple attenuation and S/N improvement of the very noisy seismic data:

- *f-k* filtering, possibly iterated for various orders of multiples,
- our innovative time-offset filtering using a differential operator.

For the first time, with a specific processing, a very clear Moho reflection from the Ross Sea Embayement area has been obtained, starting from standard processing results where these signals were totally masked by noise.

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