Multichannel Seismic Imaging of the Northern Andean subduction margin in Ecuador : preliminary seismic processing results from HIPER campaign

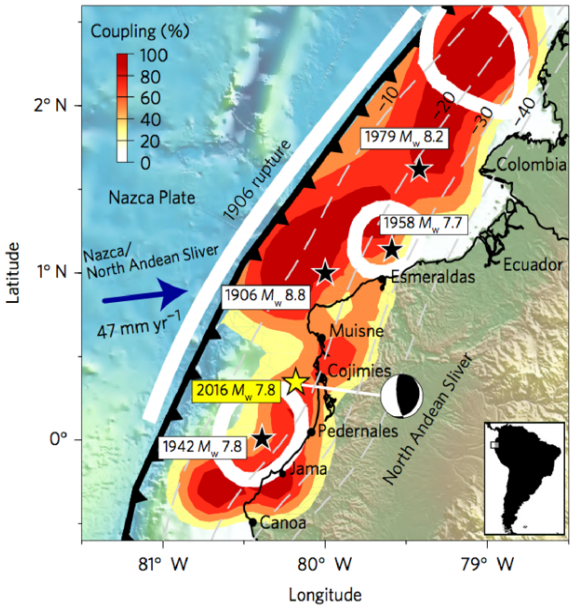


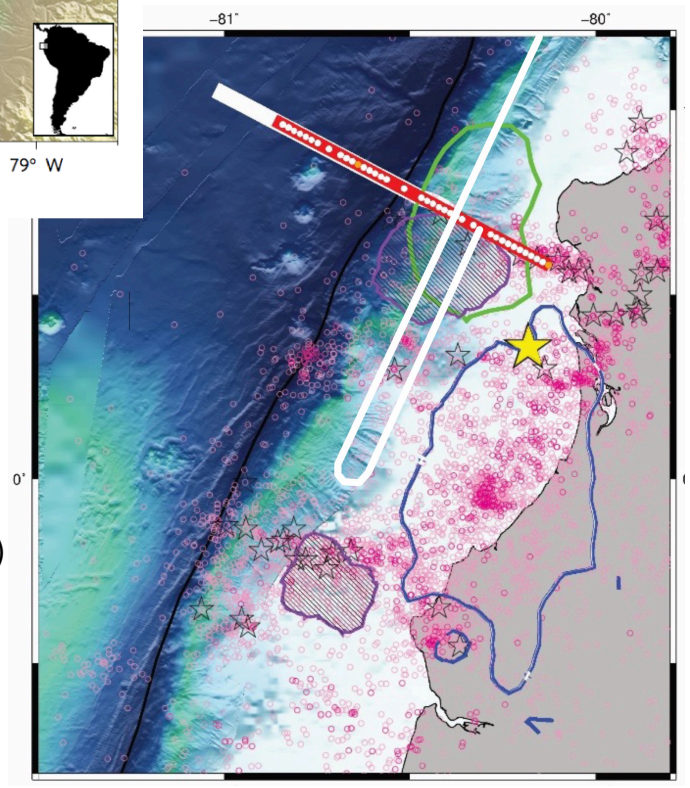
Laure SCHENINI [1], Alexandra SKRUBEJ [1], Mireille LAIGLE [1], Alessandra RIBODETTI [1], Laure COMBE [1], Audrey GALVE [1], Andreas RIETBROCK [2], Philippe CHARVIS [1], Bernard MERCIER DE LÉPINAY [1], Boris MARCAILLOU [1]

[1] Université Côte d'Azur, IRD, CNRS, Observatoire de la Côte d'Azur, Geoazur, 06560 Valbonne, France

[2] Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, 76187, Germany

The Active Northern Ecuadorian Margin





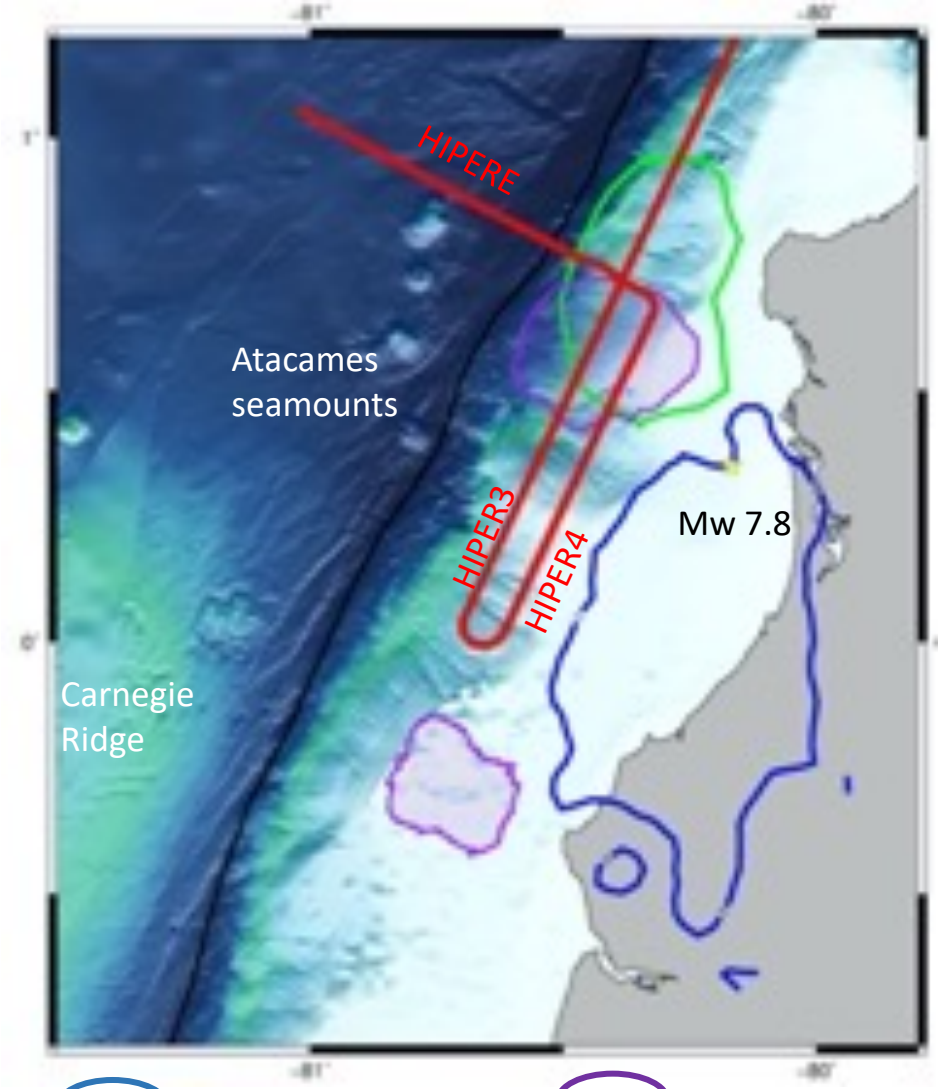
- 2016 Pedernales earthquake rupture zone
- SSE (Vaca et al, 2018)
- Afterslip (Rolandone et al, 2018)
- MCS lines
- WAS lines
- Aftershocks (Agurto et al, 2019)

- 5 large earthquakes: 1906 Mw 8.8 mega-earthquake (Kanamori & Given, 1981) followed by three 7.8-8.2 earthquakes in 1942, 1958, 1979 and in 2016, Mw 7.8 Pedernales earthquake (Nocquet et al., 2016)
- Various slip behaviours : seismic slip, afterslip, SSE

Objectives of HIPER survey:

- Image the roughness of the plate interface down to the 2016 Pedernales earthquake rupture zone
- Mapping faults affecting the downgoing and upper plate
- Mapping fluids on interplate interface

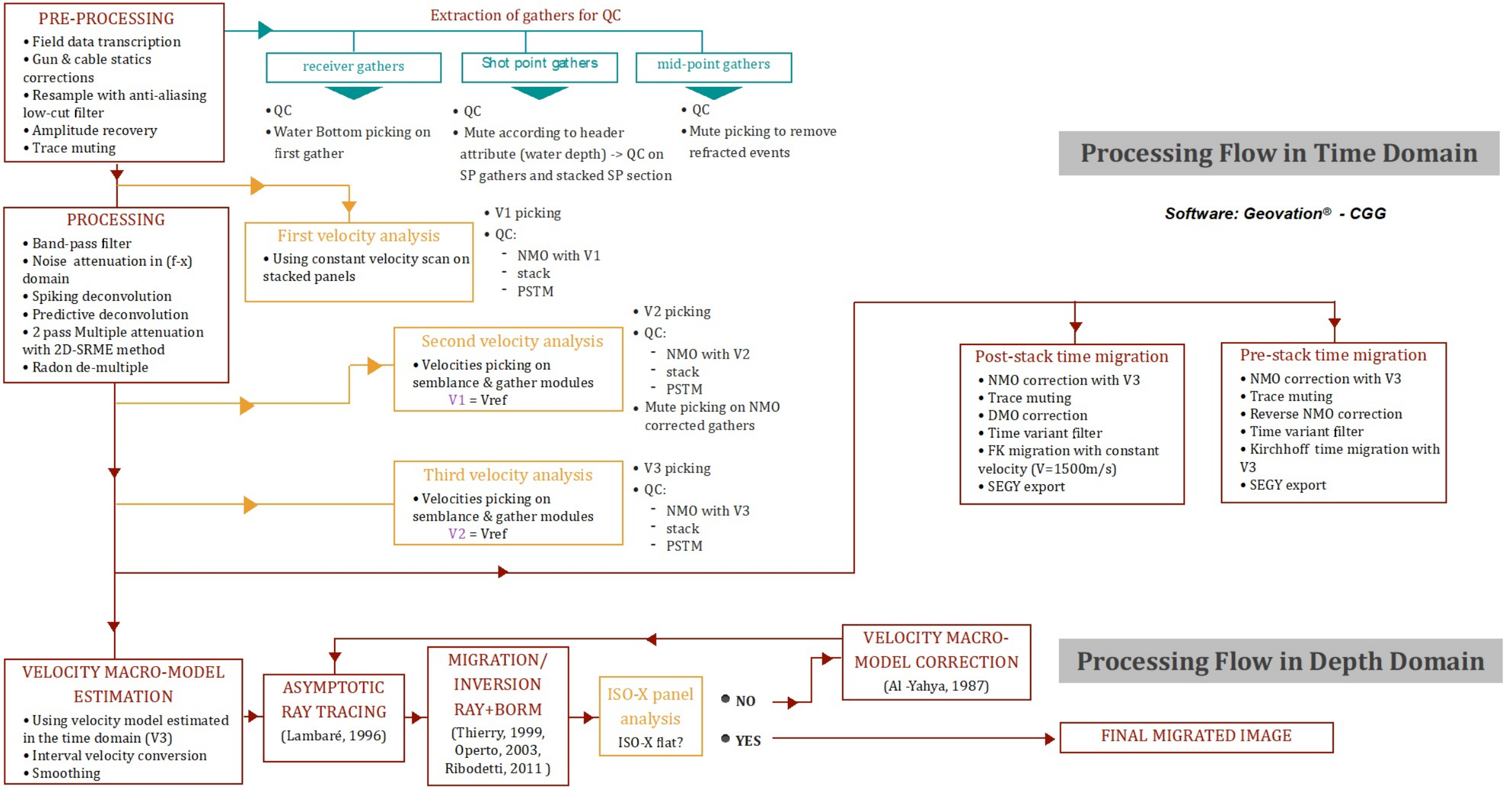
HIPER Experiment, March 2020, onboard R/V *L'Atalante*



Multichannel reflection data (MCS)

- Recorded using a **6 km-long**, **960-channel streamer** from **IFREMER**
- 3 deep penetration multichannel seismic reflection profiles
  - 1 trench normal profile
  - 2 trench parallel profiles
- Source of **16 airguns** (from 150 to 520 in3 each) ➡ **81.8 l** (4990 in3)
  Shot interval: **100 m**
- Dominant frequencies range between **~5 Hz and ~50 Hz** with a peak at **27 Hz**
- Data processed in time domain with **CGG's Geovation** software available in Geoazur up to a pre-stack time and depth migration
- Depth imaging of MCS data dedicated to get the true geometry of reflectors will be obtained by an iterative ray+Born least-squares depth migration/inversion

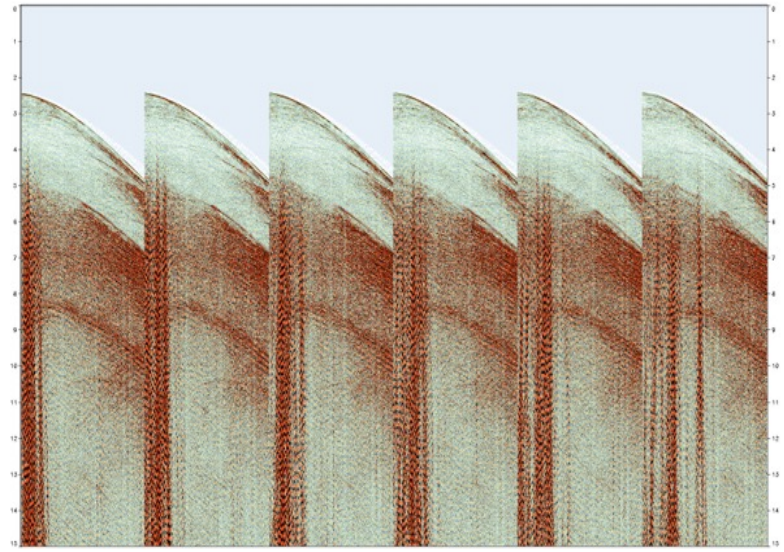
Seismic processing sequence



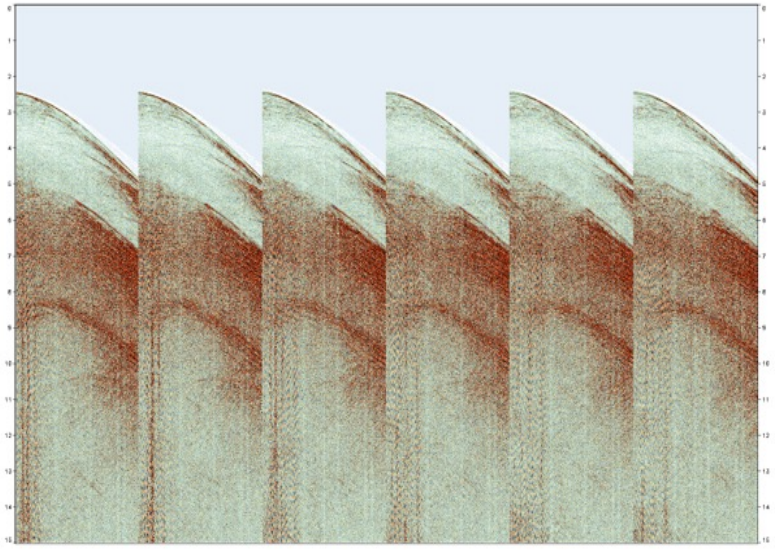
Noise attenuation

For SP contaminated by impulsive and hight amplitude noises :

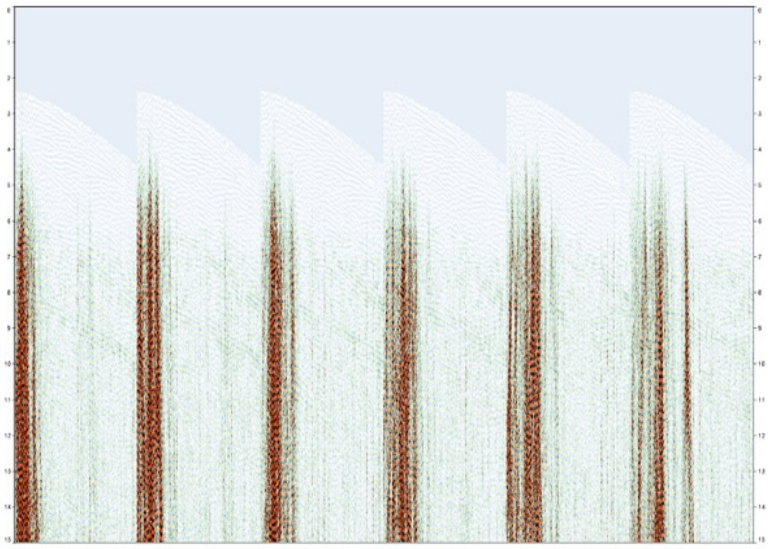
- Pre-filtering (2,5 Hz low-cut filter)
- Predictive filtering method in F-X domain over different groups of traces, works by separating the signal (assumed to be predictable in x) from non-predictable noise, preserves the signal amplitudes



Input gather



After filter

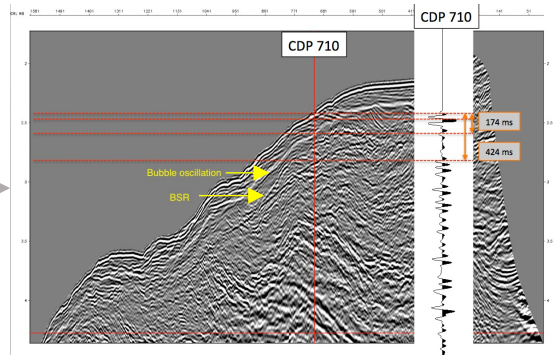


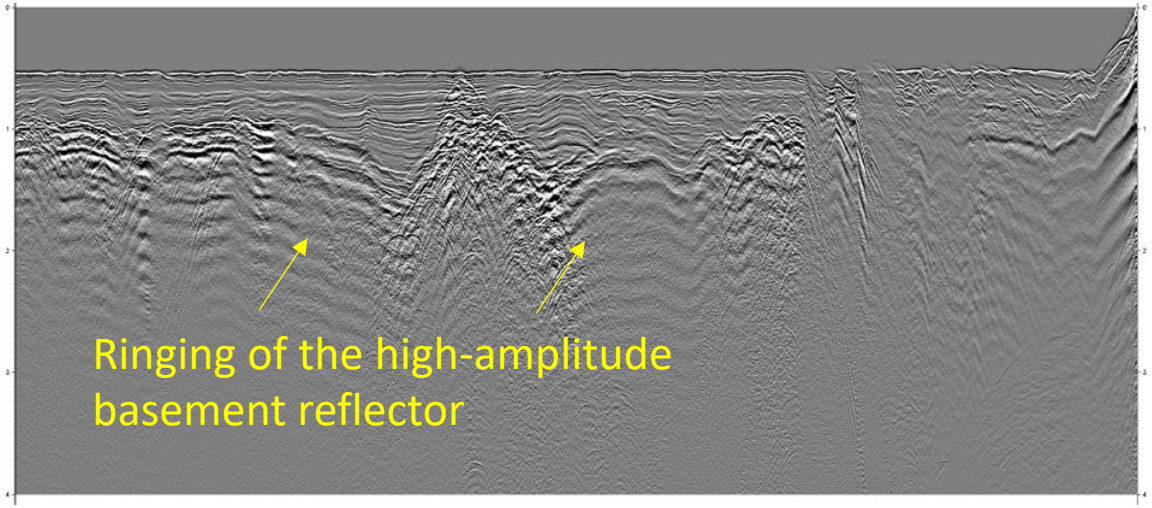
Noise removed by predictive filter

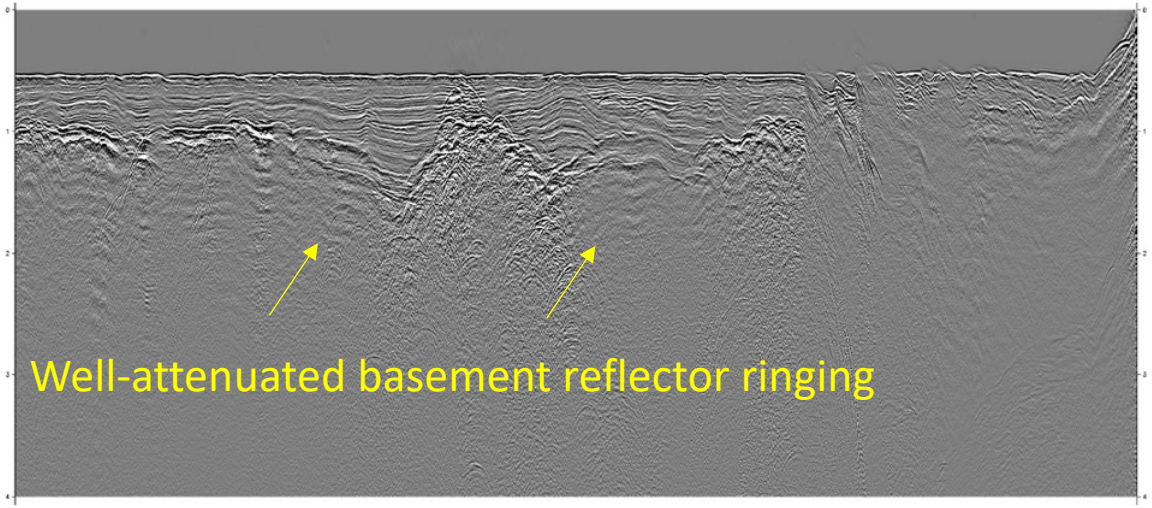
Deconvolution

For attenuation of the seismic source ringing :

- Spiking deconvolution to compress the wavelet (small operator length)
- Predictive deconvolution to attenuate the bubble oscillation period of 170 ms (long operator length, short enough to preserve BSR reflector at ~400 ms below the sea-bottom)



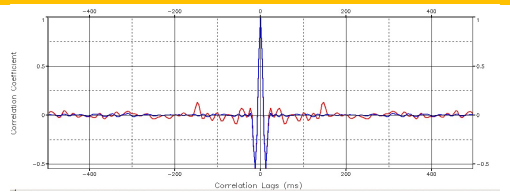




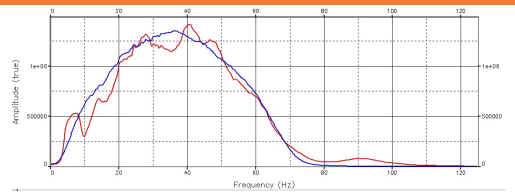
Before deconvolution: NMO correction with V=1500m/s –> stack –> static shift to flatten the sea-bottom reflector

After deconvolution: NMO correction with V=1500m/s –> stack –> static shift to flatten the sea-bottom reflector

Autocorrelation :
Red: before deconvolution
Blue: after deconvolution

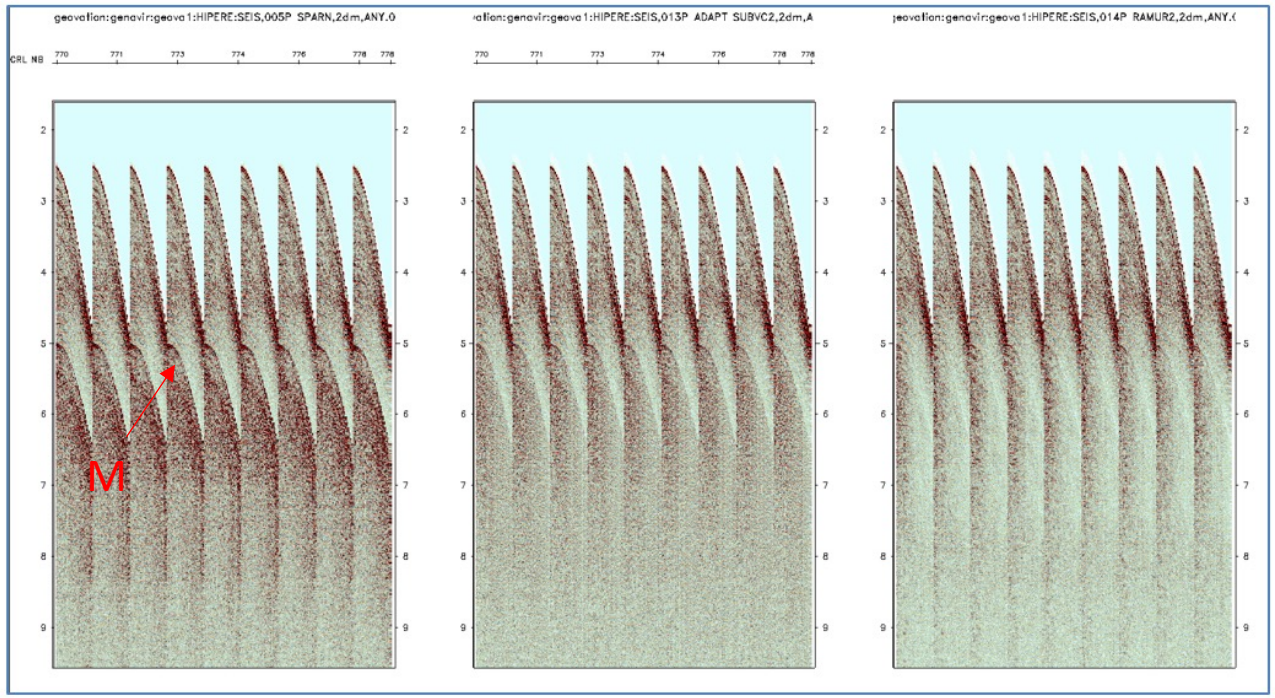


Amplitude spectrum:
Red: before deconvolution
Blue: after deconvolution



Multiples attenuation

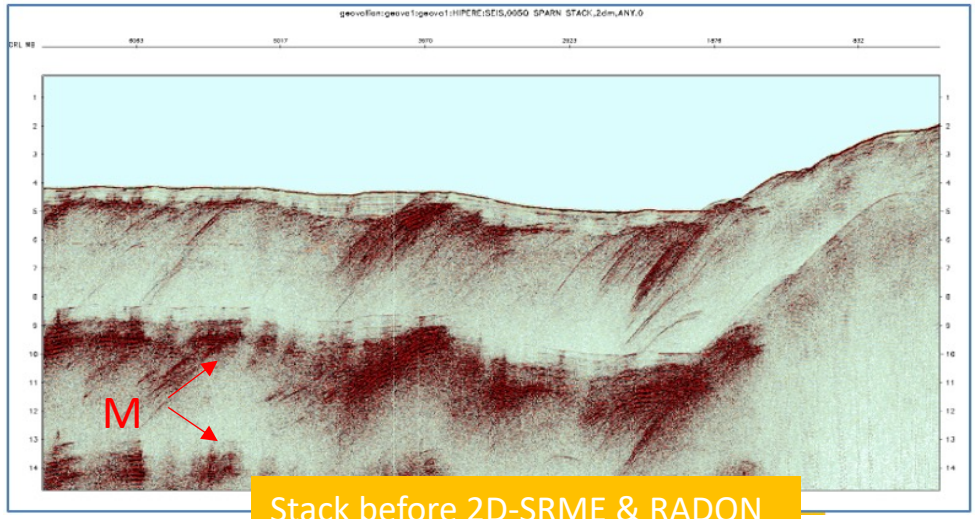
- Use of 2D-SRME method (Verschuur & Berkhout, 1997) for the sea-bottom multiple ("M" below)
- Use of Radon method to attenuate residuals and internal multiples



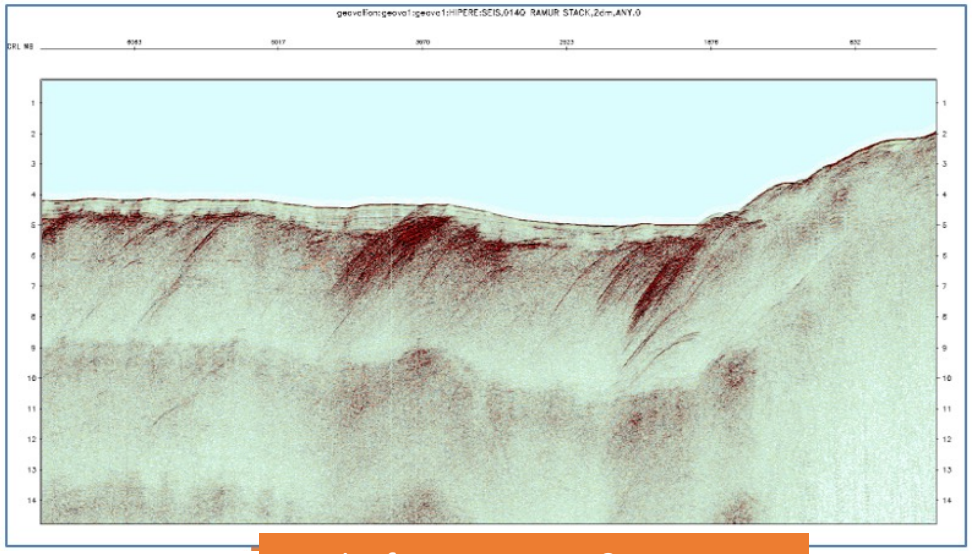
Input

Output with substracted multiples with 2D-SRME

Output with substracted multiples with 2D-SRME & RADON



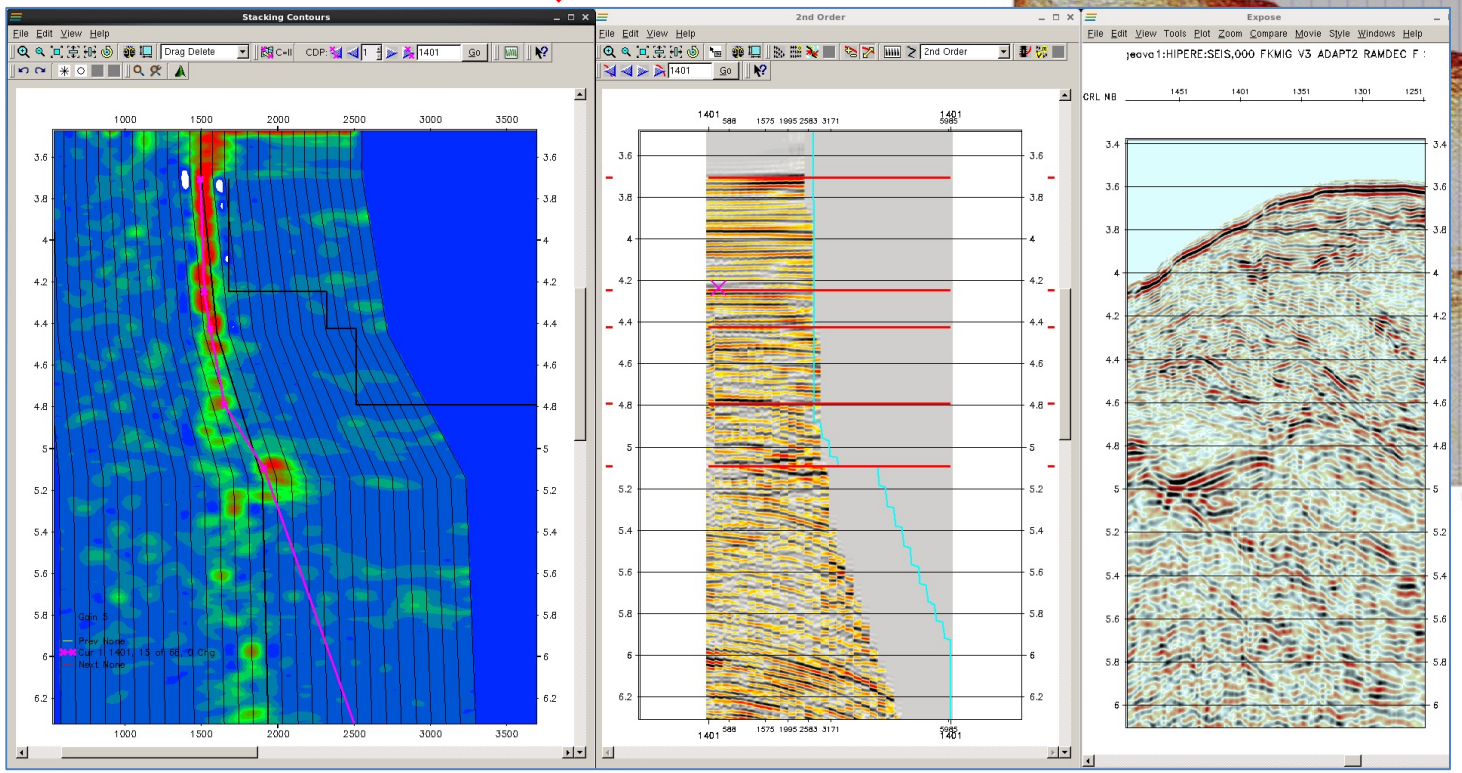
Stack before 2D-SRME & RADON

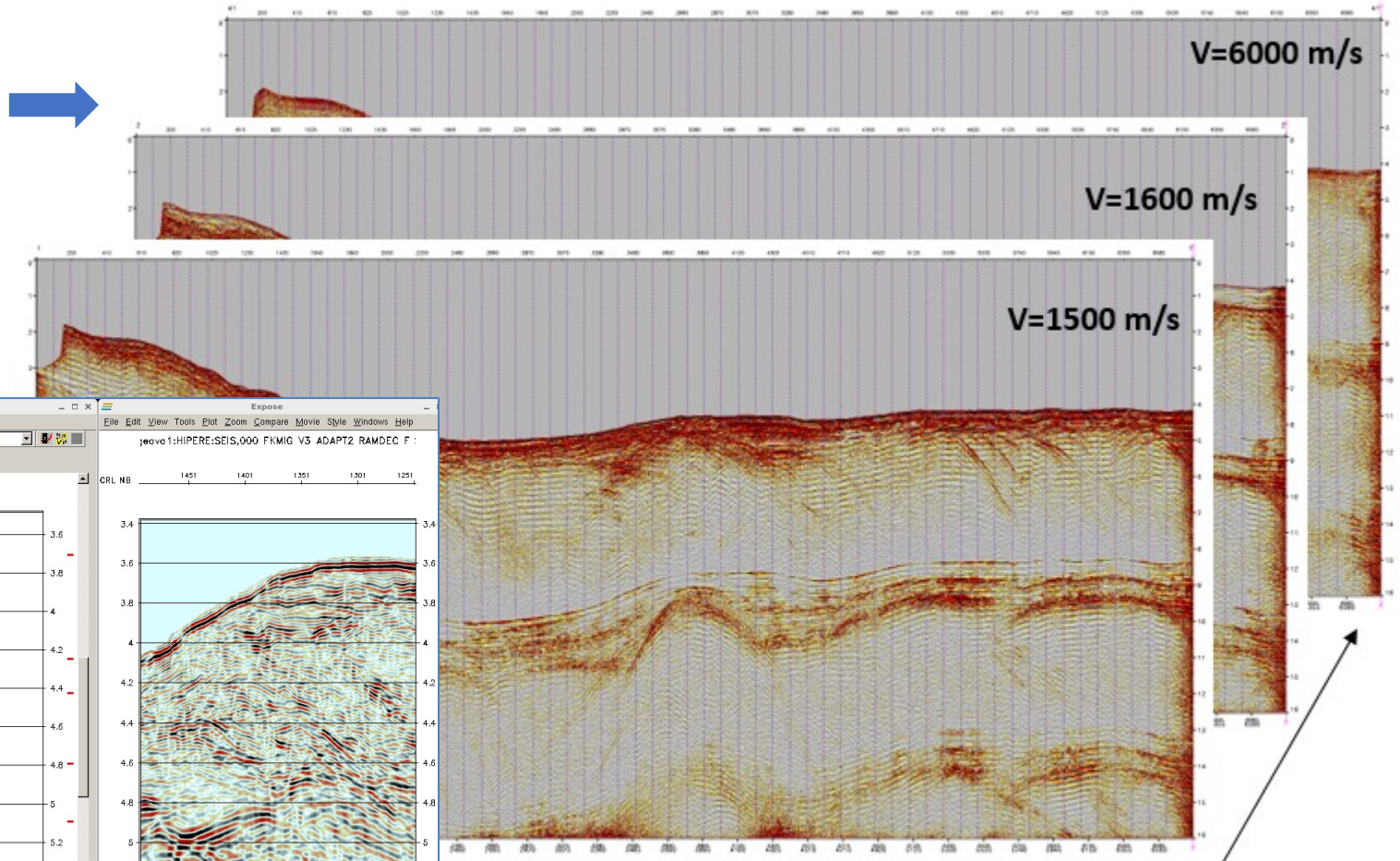


Stack after 2D-SRME & RADON

Velocity analyses in time domain

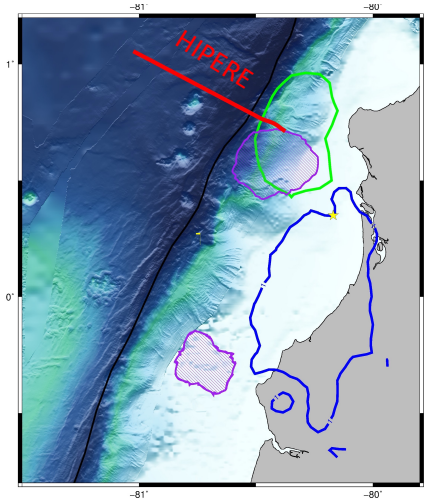
- 1st velocity analysis performed on stacked panels with Vnmo = constant value
- 2nd and 3rd velocity analysis with perturbed values of V1 on CMP gathers and velocity spectrum

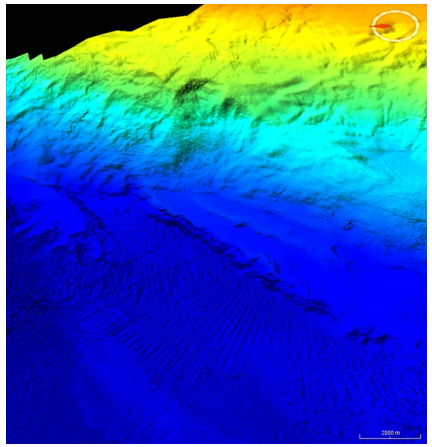




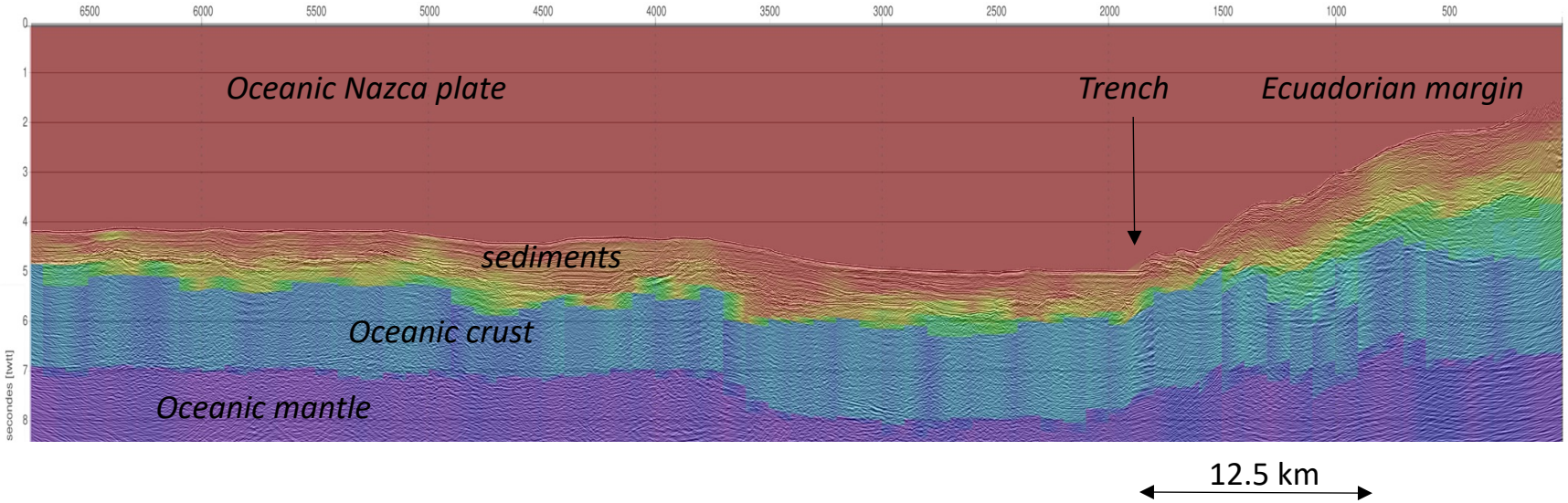
Velocity increment of 100 m/s beetween each panel

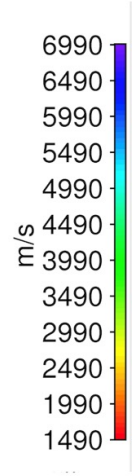
Pre-Stack Time Migration





- Velocity 2D model for Pre-stack time Migration
- HIPER-E line

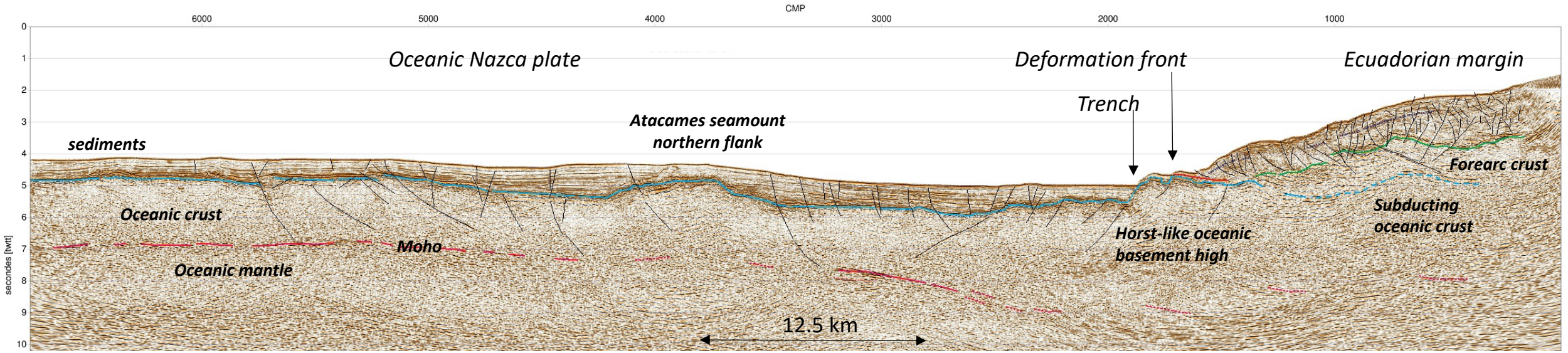




- While velocity picking, we picked interval velocities below the top of the igneous oceanic crust consistent with P velocities compilation of Christeson et al (2019)

Pre-Stack Time Migration - Interpretation

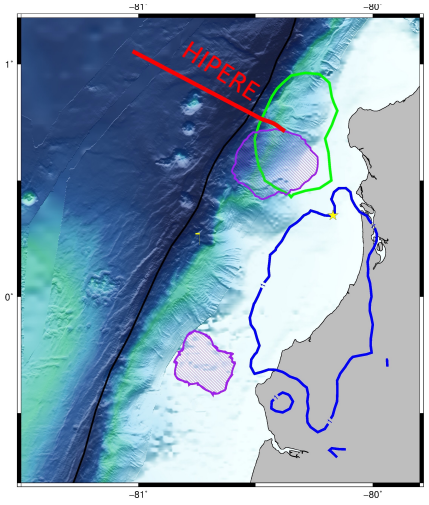
➢ Pre-stack time Migration interpretation



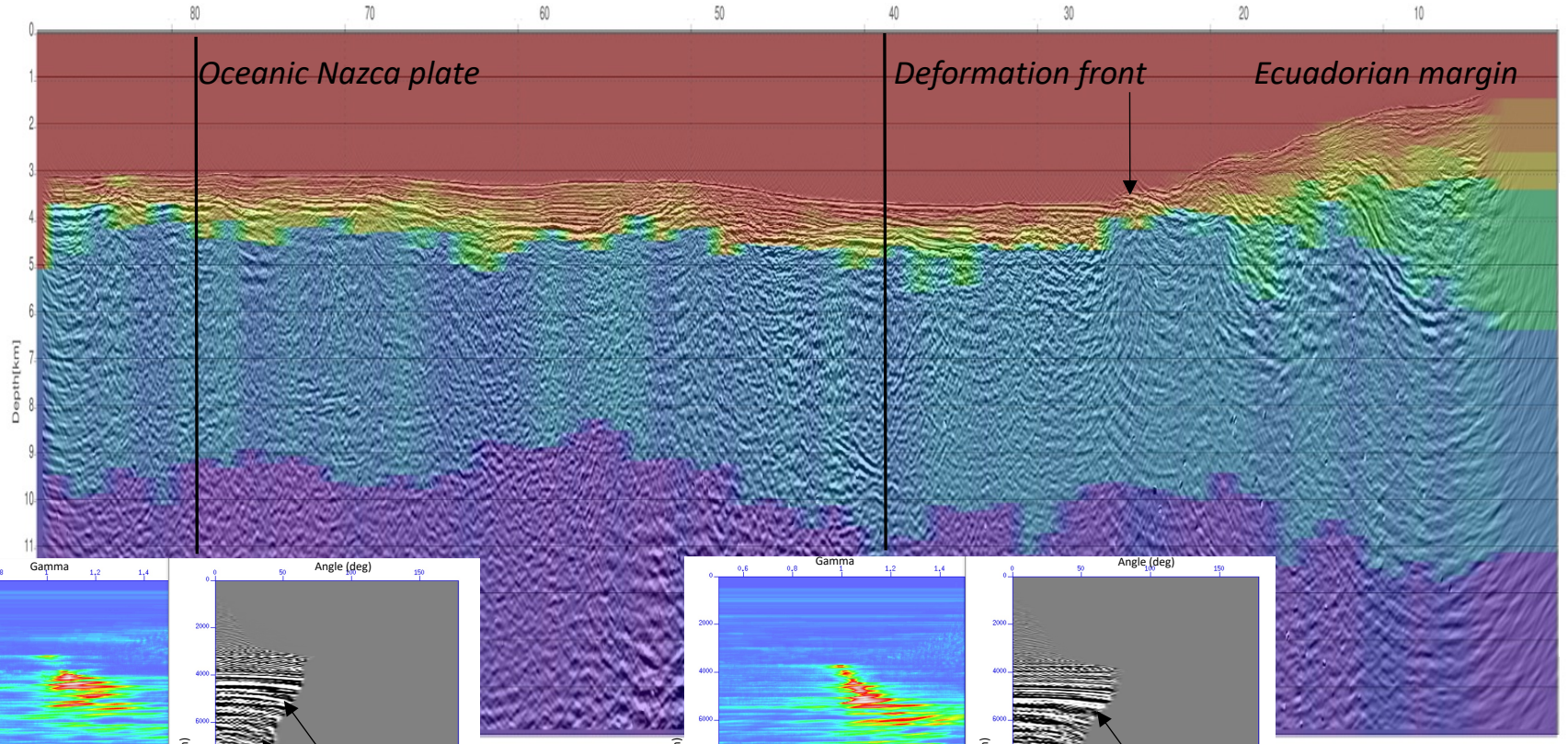
- Rough topography of the top of igneous oceanic crust (*blue*).
- Small scale rougher topography at volcanic areas (due to possibly ancient possible lava flows) at the Atacames seamounts area.
- Clear Moho reflection (*brown*).
- Numerous slab bending faults (*black*) cutting through the whole crust.
- Intra-crustal reflectivity, to be interpreted.

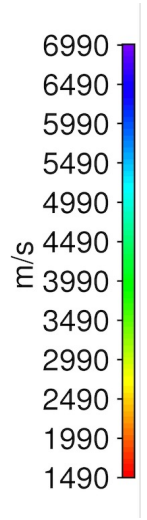
- Horst-like basement topographic high of the subduction oceanic crust (*blue*) outcroppoing at sea-bottom at the trench -> offsets locally the deformation front arcwards.
- Outcropping frontal decollement reflector topping this oceanic basement high (*red*), and difficult to identify at greater depth.
- Rough topgraphy of the forearc crust (*green*).
- Highly damaged forearc crust and faulted sedimentary deposits as in Marcaillou et al. (2016) by numerous faults (*black*).

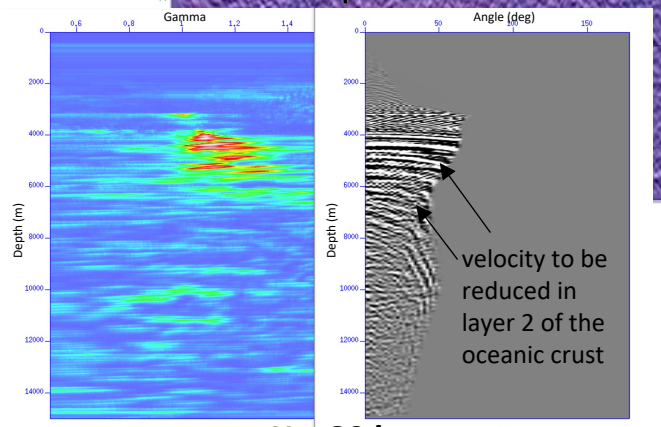
Pres-Stackk Depth migration with Vmodel derived from time velocity analysis



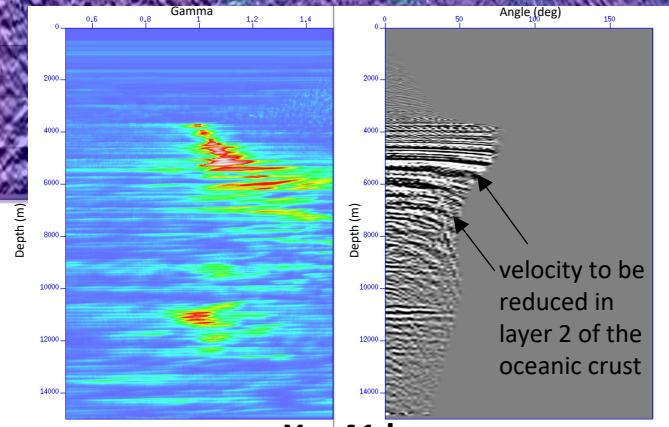
- Flattening of events in Common Image Gathers







X = 80 km

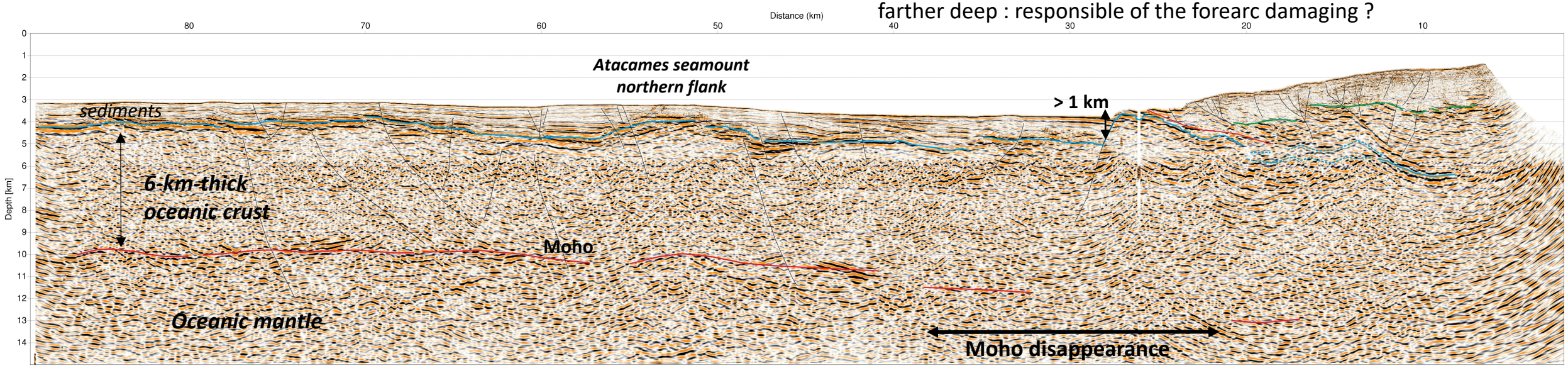


X = 41 km

Pre-Stack Depth Migration - Interpretation

- The horst-like basement topographic high is more than 1 km high
- We do not follow easily the top of the subducting oceanic crust nor the decollement
- There is possibly a subducting oceanic horst-like high or seamount farther deep : responsible of the forearc damaging ?

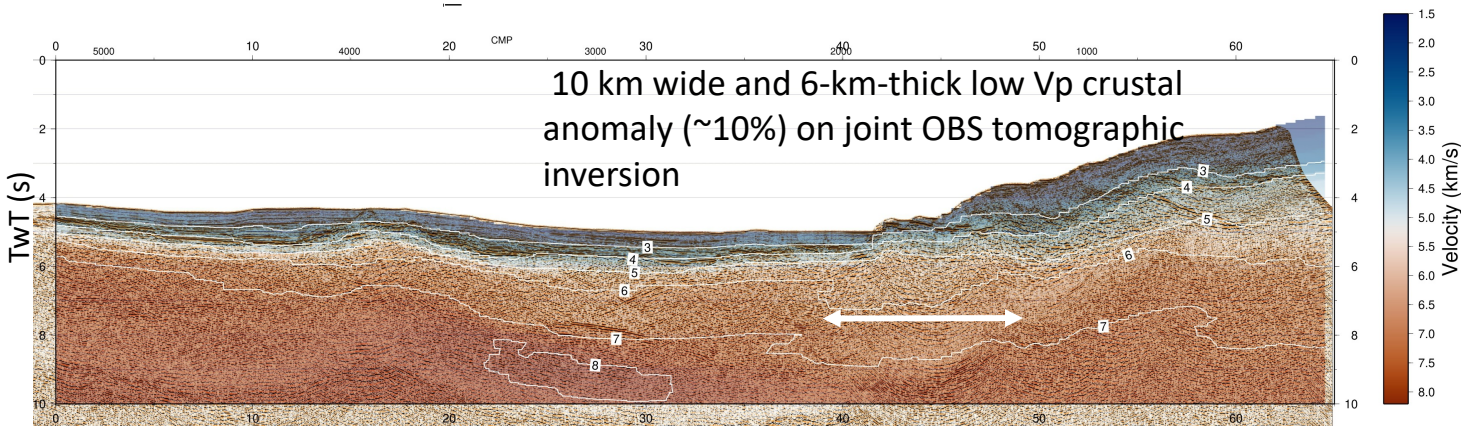
➢ Pre-stack depth Migration interpretation



Works in progress for improving depth imaging and interpretations :

- ➢ PSDM velocity analysis improvement
- ➢ joint inversion of streamer and OBS data
- ➢ reprocessing and analysis of nearby seismic lines.

All coming soon !



References and Acknowlegements

Al-Yahia, K. *Geophysics* 1989, *54(6)*, 718-729.

Lambaré, G., Virieux, J., Madariaga, R., & Jin, S. (1992). Iterative asymptotic inversion in the acoustic approximation. Geophysics, 57(9), 1138-1154.

Marcaillou, B., Spence, G., Wang, K., Collot, J. Y., & Ribodetti, A. (2008). Thermal segmentation along the N. Ecuador–S. Colombia margin (1–4 N): Prominent influence of sedimentation rate in the trench. Earth and Planetary Science Letters, 272(1), 296-308.

Operto, S., Lambare, G., Podvin, P., & Thierry, P. (2003). 3D ray+ Born migration/inversion-Part 2: Application to the SEG/EAGE overthrust experiment. Geophysics, 68(4), 1357-1370.

Ribodetti A., S. Operto, W. Agudelo, J.-Y. Collot and J. Virieux. Joint ray+Born least-squares migration and simulated annealing optimization for high-resolution target-oriented quantitative seismic imaging, Geophysics, 76(2), pages R23, 2011.

Verschuur, D.J., Berkhout, Wapenaar. Adaptive Surface-Related Multiple Elimination - Geophysics,Vol 57, No 9, September 1992, p1166-1176.

Berkhout, A. J., & Verschuur, D. J. (1997). Estimation of multiple scattering by iterative inversion, Part I: Theoretical considerations. Geophysics, 62(5), 1586-1595.

Acknowledgments : We are grateful to S. Sambolian and S. Operto who parallelised the PSDM migration code.