# Following Seismic Depth Imaging Technology for the Mexican Oil Industry: Experiences and Lessons Learned*

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## Abstract

We have followed seismic depth imaging technology for the Mexican oil industry (Instituto Mexicano del Petróleo, IMP, and Petróleos Mexicanos, PEMEX) for several years. As researchers and practitioners, getting to know the latest advances and the road ahead in geophysical technologies is always of paramount importance. Mostly, while following university research consortia and technical literature, and attending technical meetings and workshops. This paper outlines experiences and lessons learned from what did work and did not work for us when trying to facilitate communication between geologists and geophysicists. As technology followers, we provided a communication channel to catch up with the latest techniques and to understand the theory behind them, also provided technical assistance to IMP and PEMEX practitioners and researchers during the lapse 2009-2015. In particular, we focused on seismic imaging tools like RTM (reverse time migration) LSRTM (least squares RTM), layer-based and grid-based tomography, FWI (full waveform inversion), and methods of frequency enhancement during advanced seismic imaging. The vogue is to use available technology to obtain reliable images of the subsurface. Our objective is to improve the understanding of Mexican geoscientists about the fundamentals underlying such imaging tools and, thus, strengthen their judgment to select appropriate technologies suitable for their particular problems. We believe geoscientists can benefit from this discussion given the increasing availability of depth-migrated data in the Mexican oil industry.

## Reference Cited

Chávez-Pérez, S., and L. Vargas-Meleza, 2008, Enhanced Imaging Workflow of Seismic Data from Chicontepec Basin, Mexico: The Leading Edge, v. 27/3, p. 352-359.

**IMP**
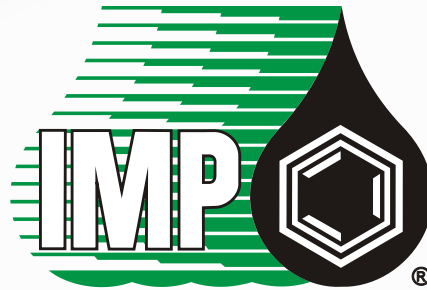
**INSTITUTO MEXICANO DEL PETRÓLEO**

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# Experiences and Lessons Learned

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# Agenda

➢ **Introduction**

➢ **Work scheme**

➢ **Academic research consortia**

➢ **Technological workshops**

➢ **Benefits for PEMEX**

➢ **Summary and future work**

➢ **Acknowledgments**

# Introduction

**Some needs:**

➤ **Technological gatekeeping, training, and research**

➤ **Transition from time (PSTM) to depth (PSDM) domain concepts**

➤ **Computational reproducibility & open source tools**

➤ **Human resources shortage**

# Introduction

**PEMEX – Technology follower**

**IMP – R&D Center**

## Technological gatekeeping

**Technical assistance in monitoring, adapting, and developing geophysical technology**

# Introduction

## Enhanced imaging workflow of seismic data from Chicontepec Basin, Mexico

SERGIO CHÁVEZ-PÉREZ and LILIANA VARGAS-MELEZA, Instituto Mexicano del Petróleo, Mexico City, Mexico

Strecker et al. (2003) show a recent example of cascading workflows to progressively mine seismic data for information. Thus, for multiple seismic attribute volumes, calculated from a 3D data set, data mining can lead to a seismic facies indicator that best discriminates lithology, fluid, and geometry, and finally produces a volume calibrated to rock properties.

This is the desired goal for most, if not all, interpreters. However, such data integration is not always feasible when well and seismic data do not cover the same region, when core and biostratigraphic data are scarce or unavailable, and when migrated volumes lack adequate resolution and have severe acquisition footprint problems.

In addition, turbidite reservoirs have lots of complexity, always greater than anticipated. PEMEX's renewed interest in turbidites has lead to high priority efforts to improve, with postprocessing workflows, seismic images to optimize field development.

In this article, we show the results of applying a two-step, cascading workflow to improve both vertical resolution and lateral delineation of turbidites in migrated seismic volumes acquired in Mexico's Chicontepec Basin.

**Geologic overview.** PEMEX Exploration and Production generously agreed to let us use the latest prestack time imaging result of 3D seismic data obtained in 1999, in the Chicontepec Basin (Veracruz, Mexico), a very important portion of the producing onshore sector (Figure 1).



Figure 1. Location map of a portion of Chicontepec Basin, Mexico, near Poza Rica, Veracruz. The red rectangle shows the approximate location of the Agua Fría-Coapechaca-Tajín data volume.

# Introduction

**Fundamental interest in exploration seismology**
**Improve Subsurface Imaging**

**Resolution**

- **Vertical resolution enhancement**
  **From data acquisition to data interpretation**
- **Lateral resolution enhancement**
  **Seismic migration methods**

**Detection**

- **Seismic attributes**
- **Spectral decomposition**

# Introduction

**Our efforts have influenced PEMEX exploration practice**

**PEMEX practitioners:**

✓ **Do their job much better,**

✓ **Understand better what they do (or are going to do), and**

✓ **Generate better products for the production stage**

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# Work Scheme

**Technical assistance in monitoring, adapting, and developing geophysical technology**
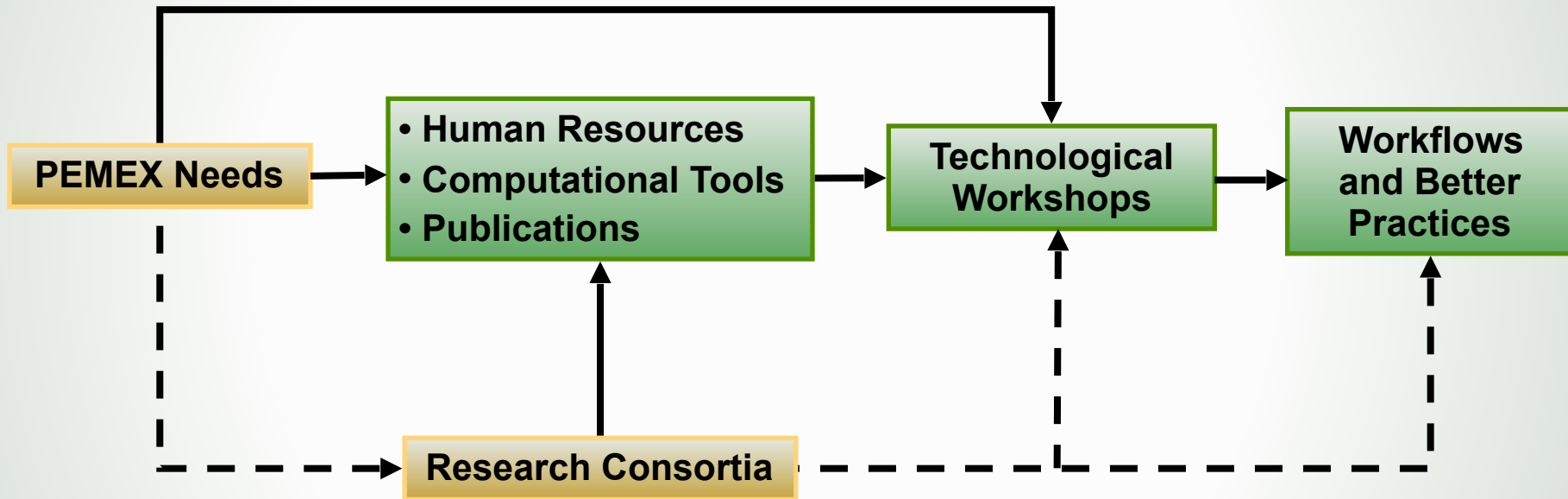


**Benefits:**
- **Knowledge generation and transfer**
- **Technological gatekeeping**
- **Training and research**

# Agenda

- ➢ Introduction

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- ➢ Summary and future work

- ➢ Acknowledgments

# Academic Research Consortia

## *AASPI*

## *Attribute-Assisted Seismic Processing and Interpretation*

**University of Oklahoma, OK, USA**

**Geometric Attributes, Structurally Oriented Filtering and Acquisition Footprint Attenuation**

**Two PEMEX Master of Science Students**

# Academic Research Consortia

## *SEP*

### *Stanford Exploration Project*

**Stanford University, CA, USA**

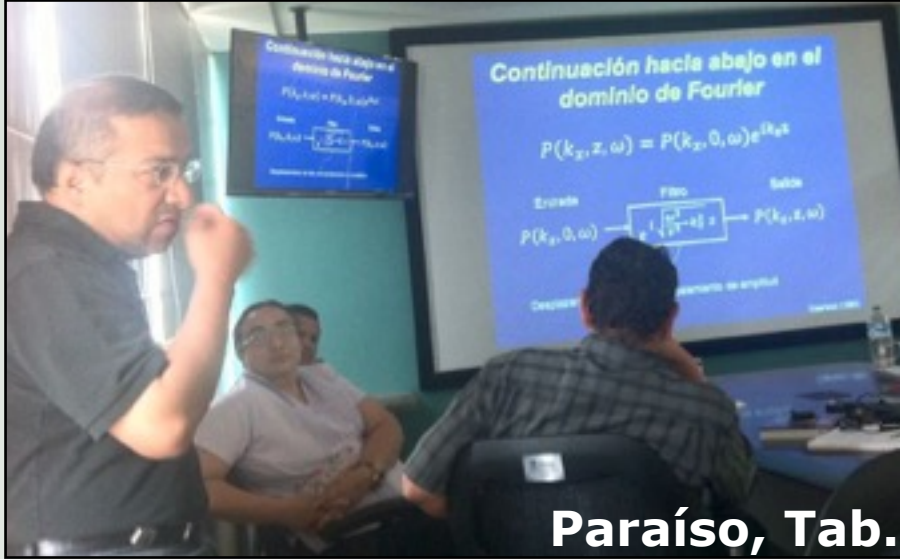**Velocity Model Estimation, Seismic Modeling, RTM, FWI, and Anisotropy**

**One Pemex PhD Candidate**

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# Technological Workshops



Paraíso, Tab.

Cd. del Carmen, Cam.

Villahermosa, Tab.

# Relevant Topics

- **Depth migration fundamentals: RTM, LSM, and FWI**

- **Quality Factor: Q-PSTM, Q-PSDM, Q-FWI**

- **Present and future of seismic imaging techniques, velocity and Q-seismic tomographies**

- **Seismic attributes: Use, abuse, and trends**

- **Velocity model estimation and seismic anisotropy**

- **Technological highlights from SEG and consortia meetings (AASPI, CSIM, and SEP)**
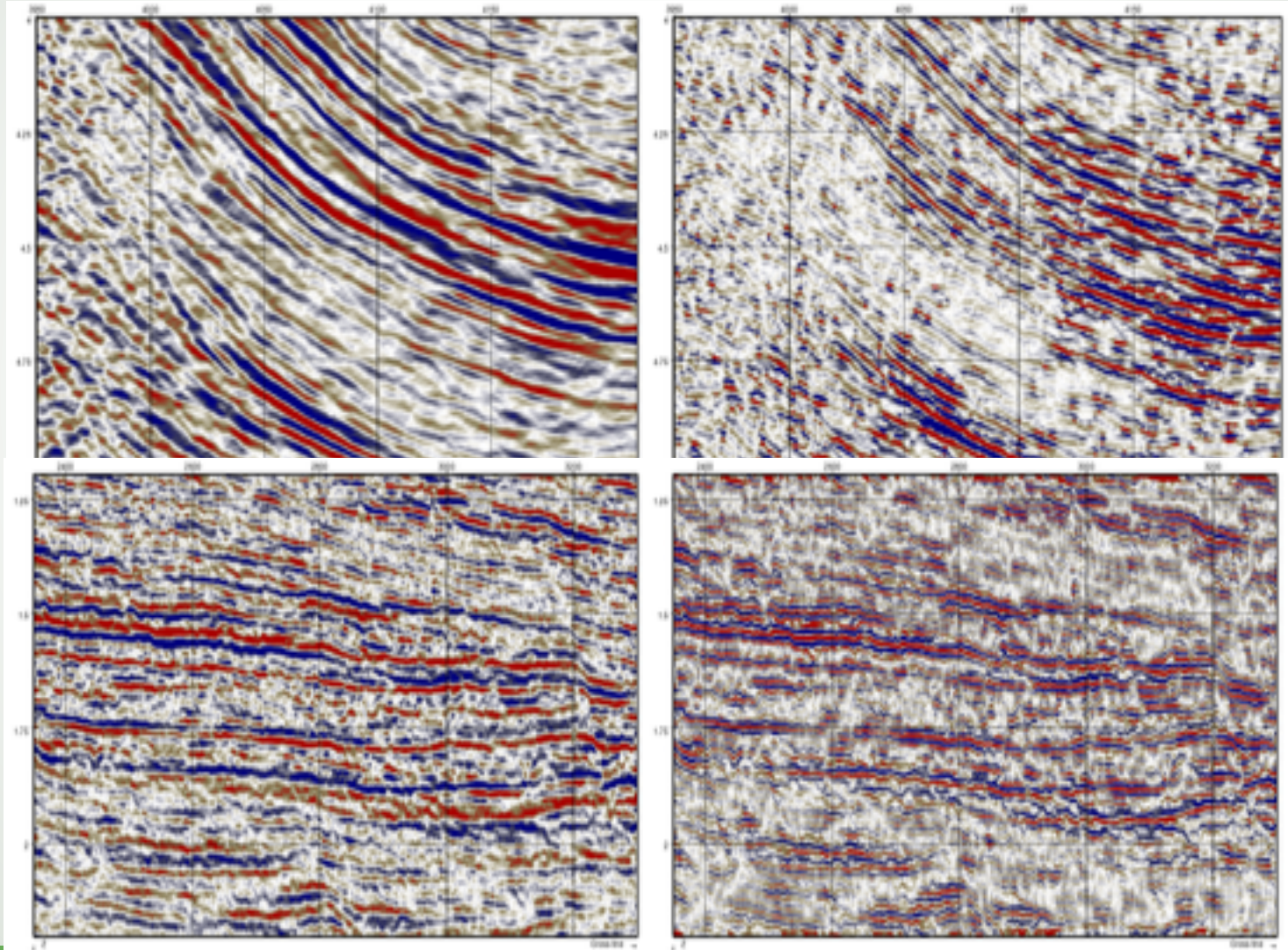
# Interaction with Practitioners

## Main Topics

- Azimuthal seismic data processing

- Seismic anisotropy

- Rock physics

- Acquisition footprint and geometric attributes

- Spectral decomposition

- Seismic volume merging

- Frequency (resolution) enhancement

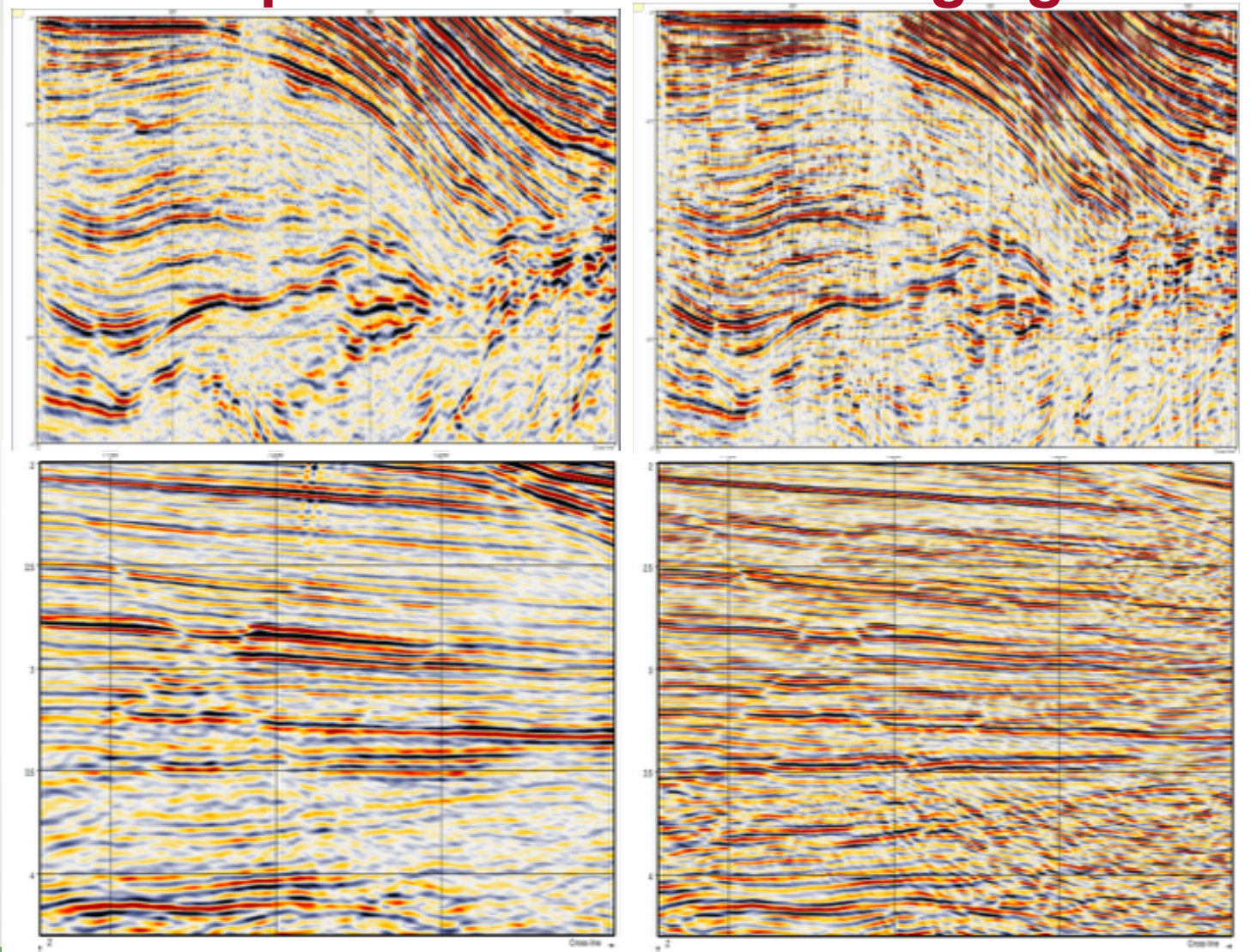# Frequency enhancement

## Improve Subsurface Imaging



**Before**                    **After**

# Frequency enhancement

## Improve Subsurface Imaging



**Before**          **After**

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# Benefits for PEMEX

## Seismic bandwidth extension

### Acquisition

- **Variable-depth streamer**
- **Over/Under towed streamer**
- **Dual-sensor towed streamer**
- **...**

### Processing

- **Deconvolution**
- **Spectral balancing**
- **...**

### Imaging

- **Migration deconvolution**
- **LSRTM**
- **...**

### Post processing

- **Derivatives**
- **Phase multiplier**
- **Loop deconvolution**
- **Spectral blueing**
- **Wavelet transform**
- **Reflectivity inversion**
- **SOF + Spectral balancing**
- **...**

**Best**

**Worst**

**Wish list**

# Benefits for PEMEX

- **Knowledge generation and transfer**

- **Technological gatekeeping**

- **Training and research**

- **Frequency (resolution) enhancement tests**

- **Use of free open-source software**

    **e.g.** *Madagascar, Python*

- **Academic software and workflows from consortia**

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# Summary

**Our efforts have influenced PEMEX exploration practice**

**PEMEX practitioners:**

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- ✓ **Understand better what they do (or are going to do), and**

- ✓ **Generate better products for the production stage**

# Lessons Learned

➢ **Two-step flow can be effective in transferring technological and scientific information**

**Source > Gatekeeper > Practitioner**

➢ **Technological gatekeeping contributes to overcome communication boundaries**

➢ **Need to improve delivering and receiving feedback / feedforward**

# Future Work

➢ **Time (PSTM) vs Depth (PSDM) domain concepts**

➢ **PSTM vs PSDM seismic attributes**

➢ **Time vs depth domain structural uncertainty**

➢ **Computational reproducibility, open source tools, and notebooks**

# Acknowledgments