HPC for Exploration & Production

Seismic

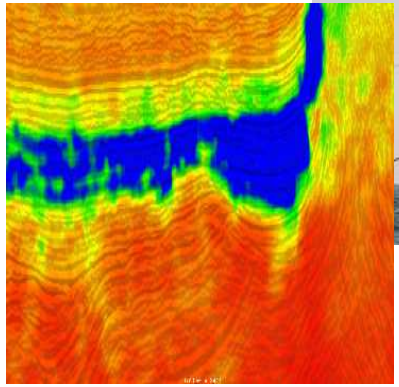
Sub-surface imaging and goals

Computing Power needs

Computing Power trends

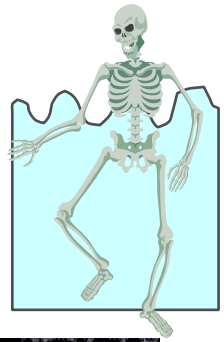
Ph Chalon

Seismic

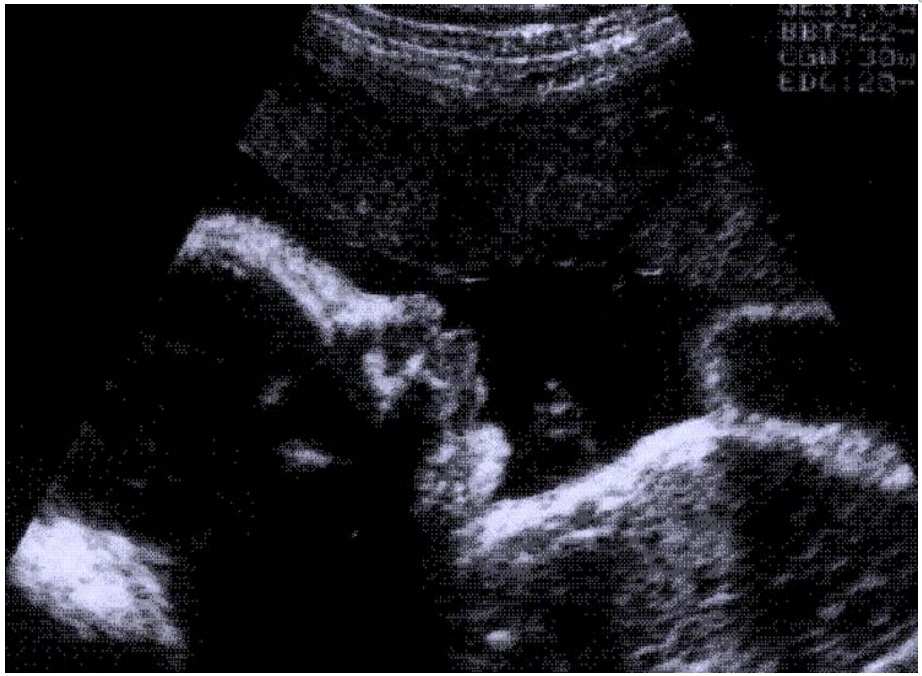


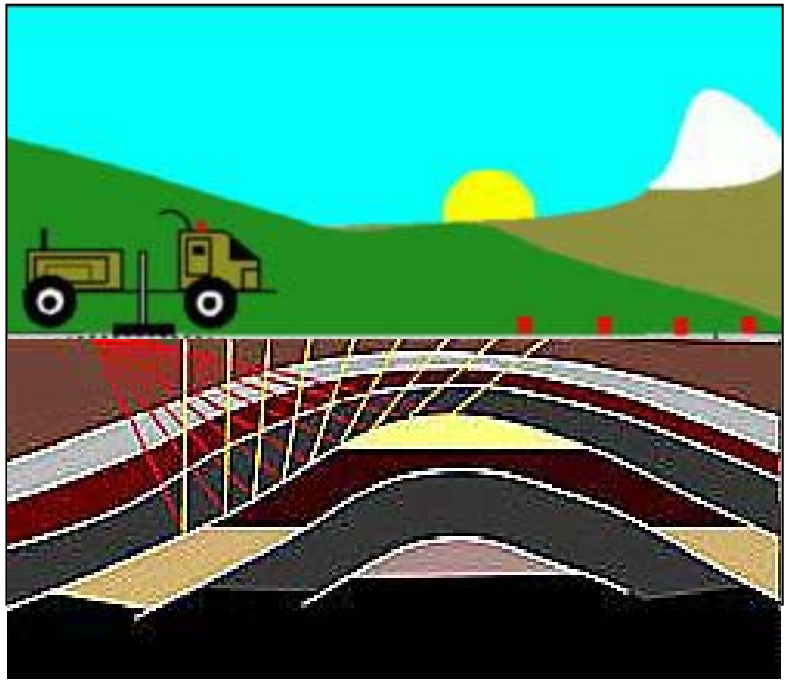
Principle

Medical Echography



Seismic



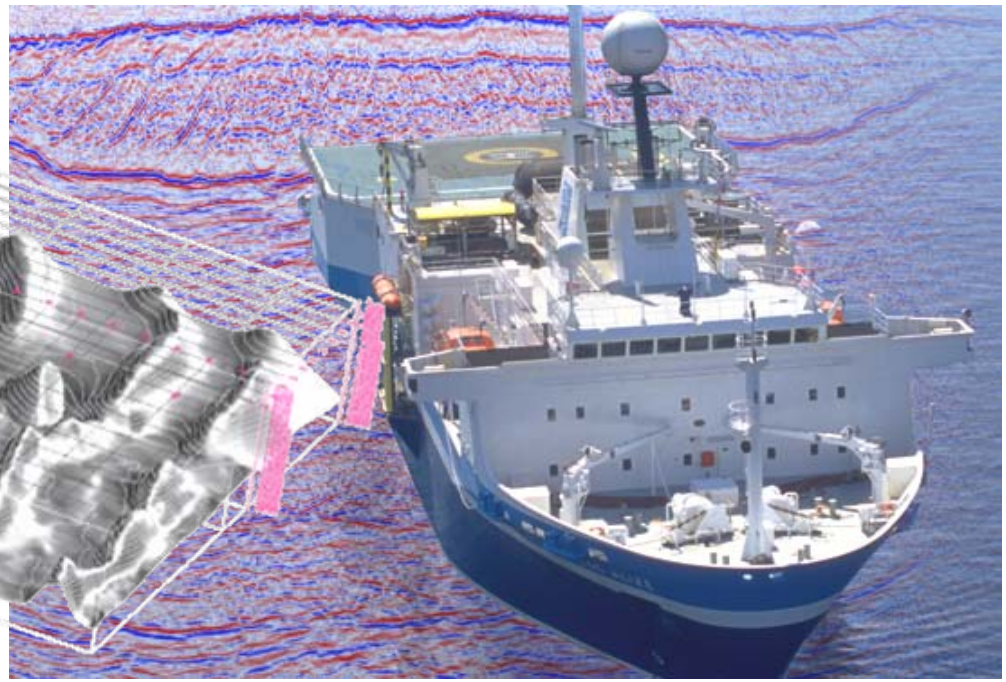


*** Signal frequency: 1 MHz**
==> Image resolution: few mm.
*** Approximately homogeneous media.**

*** Signal frequency: between 6 and 90 Hz**
==> Image resolution: some tens of m.
*** Heterogeneous media (spatial variability of density and signal velocity)**

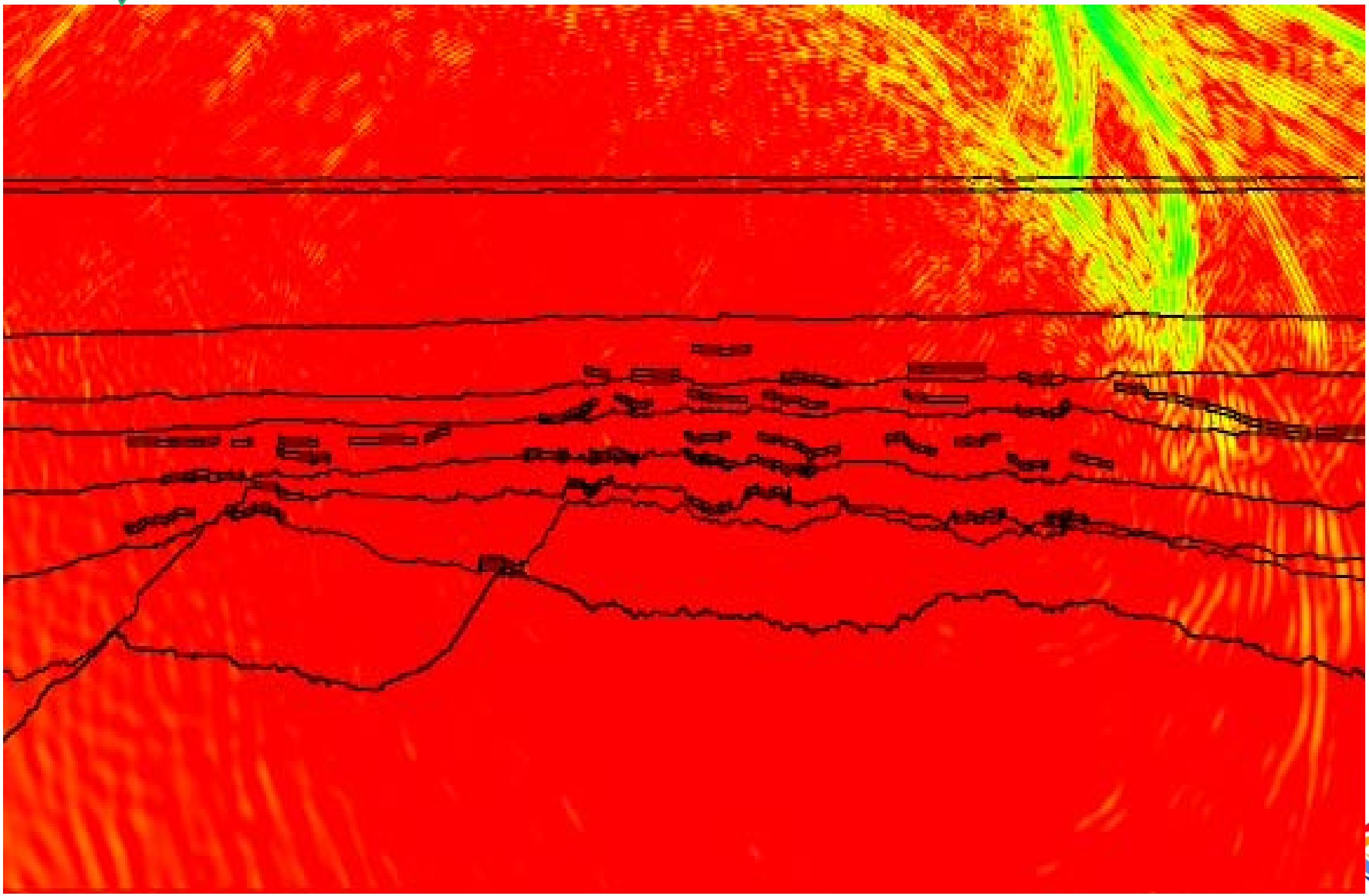
TOTAL

Data acquisition



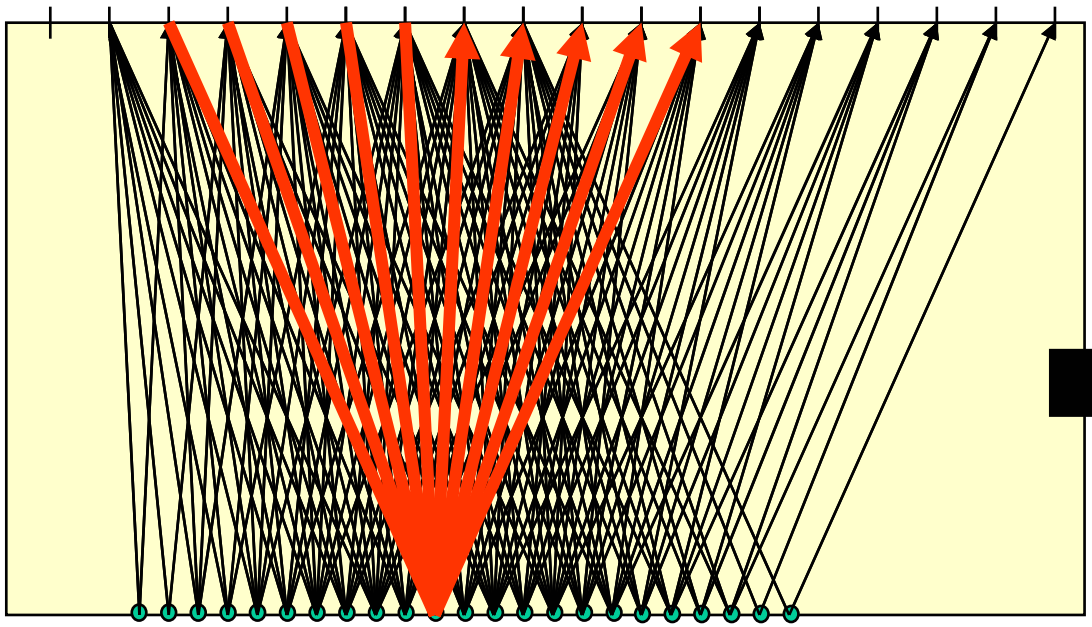
Seismic wave propagation

$$\left[\frac{1}{c^2}\frac{\partial^2}{\partial t^2}-\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\right]P(x,y,z,t)=0.$$

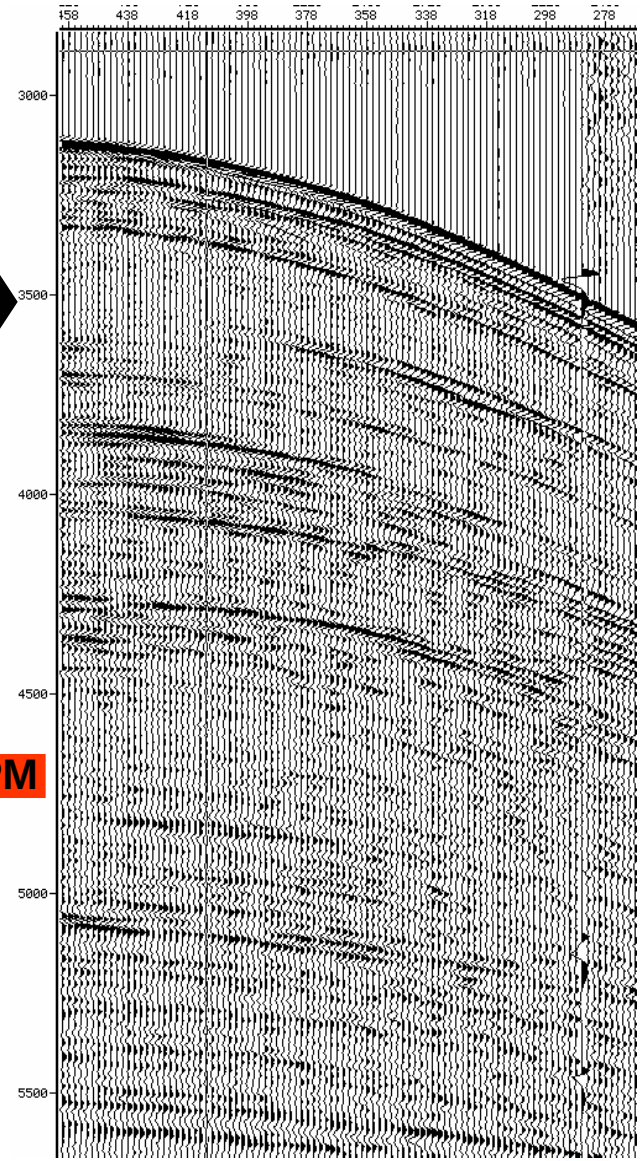


TOTAL

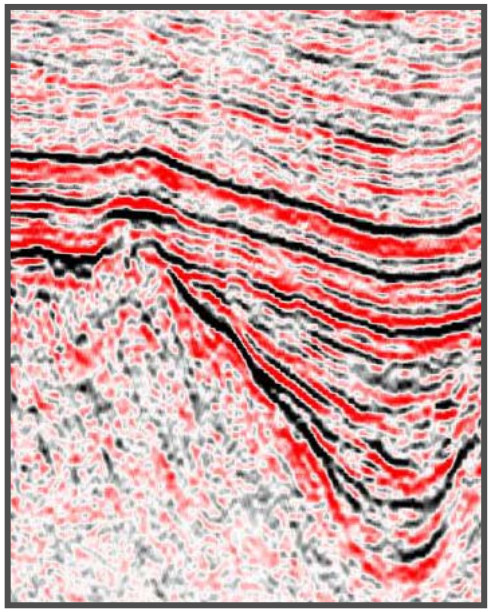
Signal processing



PT



PM



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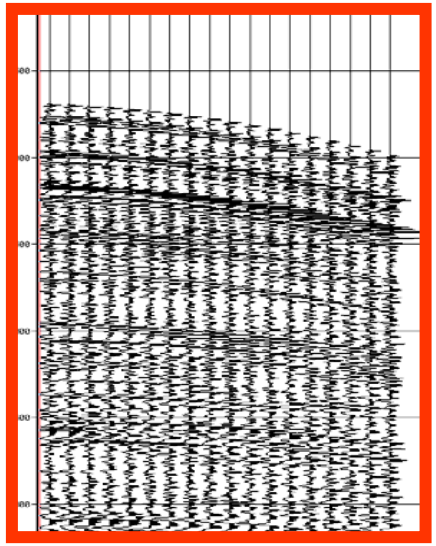
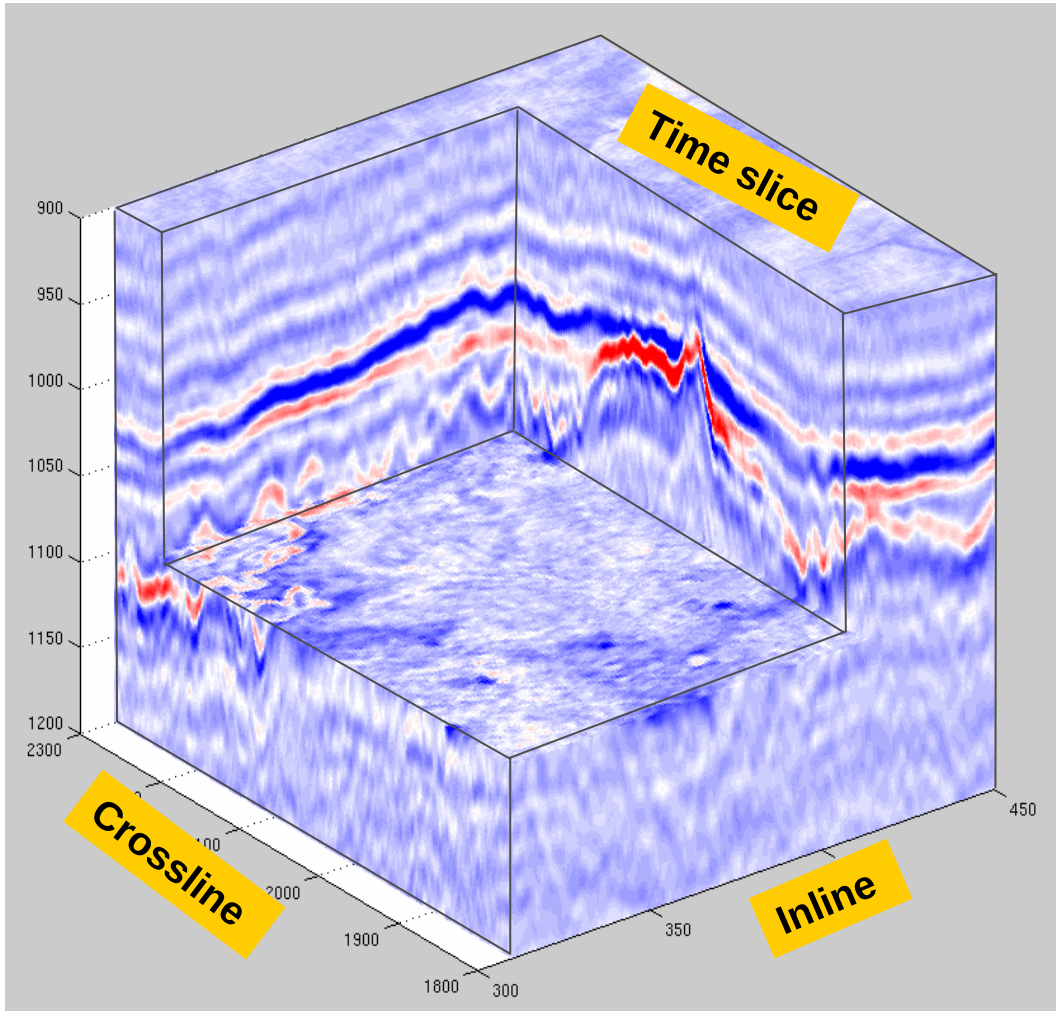


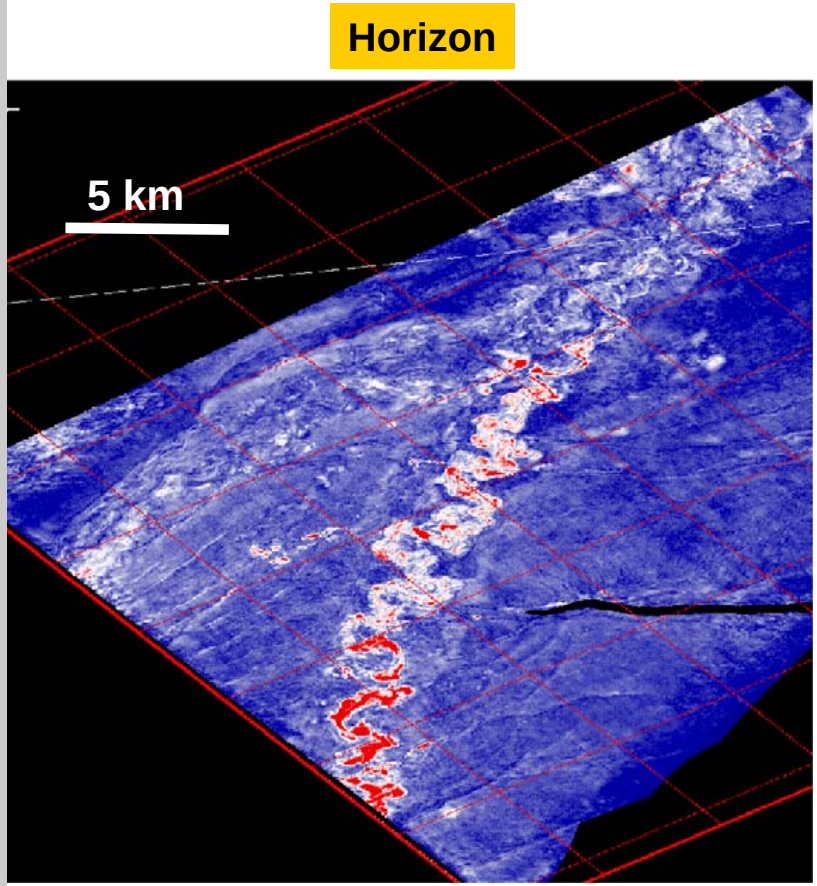
TOTAL

Seismic interpretation

Seismic (3D) generates a reflectivity cube

For interpretation purpose, information is extracted through plans or surfaces





Amplitude variations help for geological component identification

TOTAL

Sub-surface imaging and goals

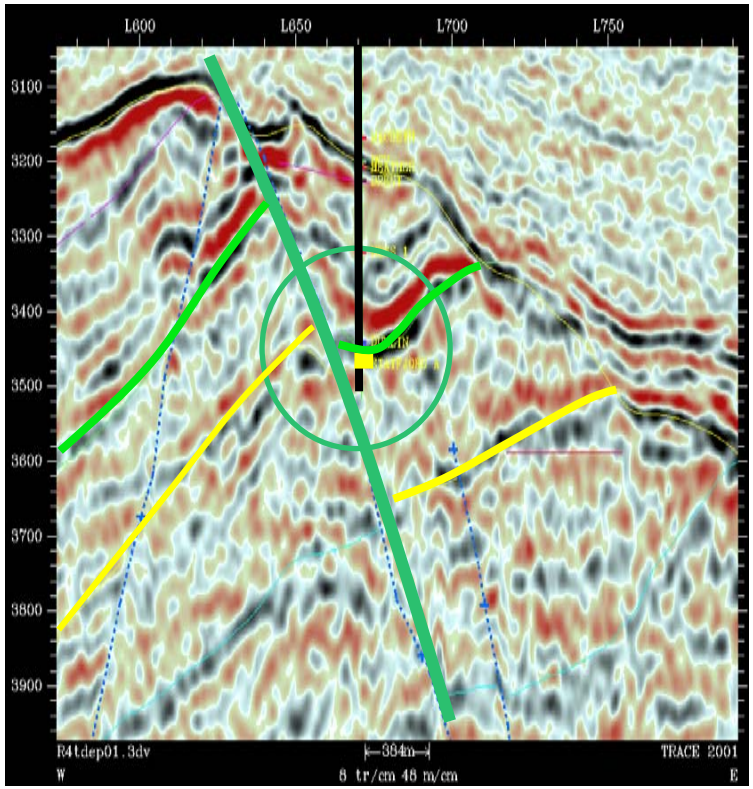
What is depth imaging ?

- **Pre-stack depth migration**
  - Depth migration algorithms for image reconstruction (through digital back-propagation of surface recorded signal) → Requires High Performance Computing (HPC).
- **A strategic technology to acquire new leases and reduce uncertainties**
  - Because it is more precise
  - Well suited for complex geological areas for which traditional methods are irrelevant
- **Permanently evolving technology: Algorithms and methodologies**
- **This technology requires geophysical skills that are not mastered by seismic contractors:**
  - Important Depth Conversion tasks
  - Important Interpretation tasks

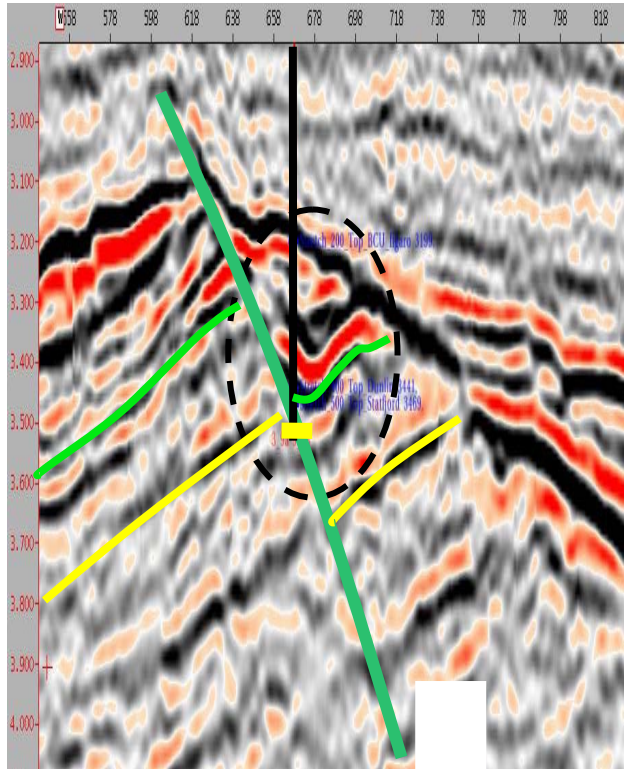
TOTAL

Production : More precision in reservoir imaging

Time - 1999



Depth - 2007

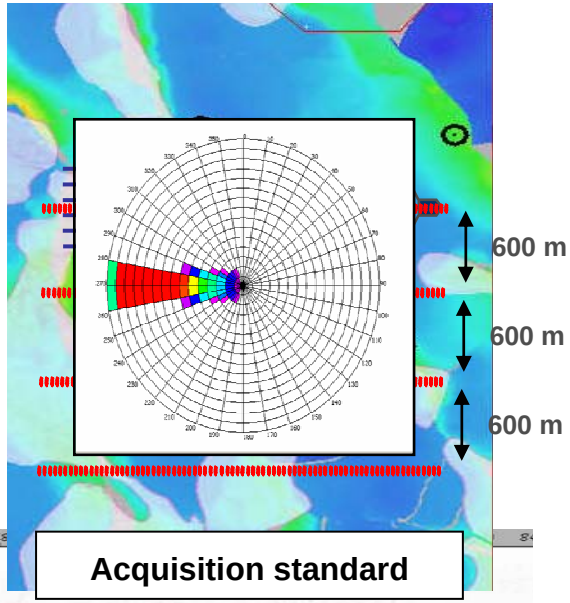


Seismic imaging improvements have a direct impact over volume estimation, well path and production monitoring (repetitive seismic)

Rock Volume Impact : + 46 %

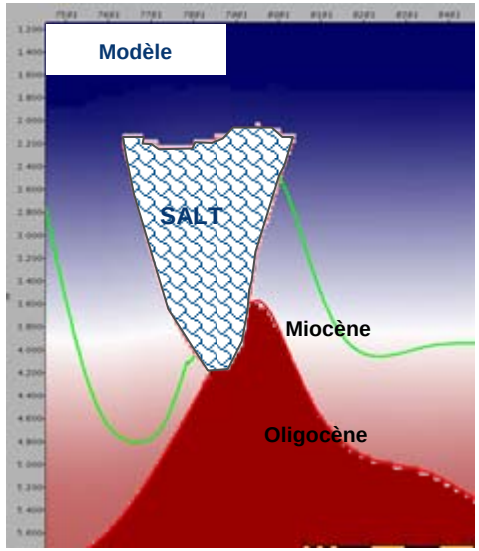
Imaging Project: 7 months
Cost: 600 k€

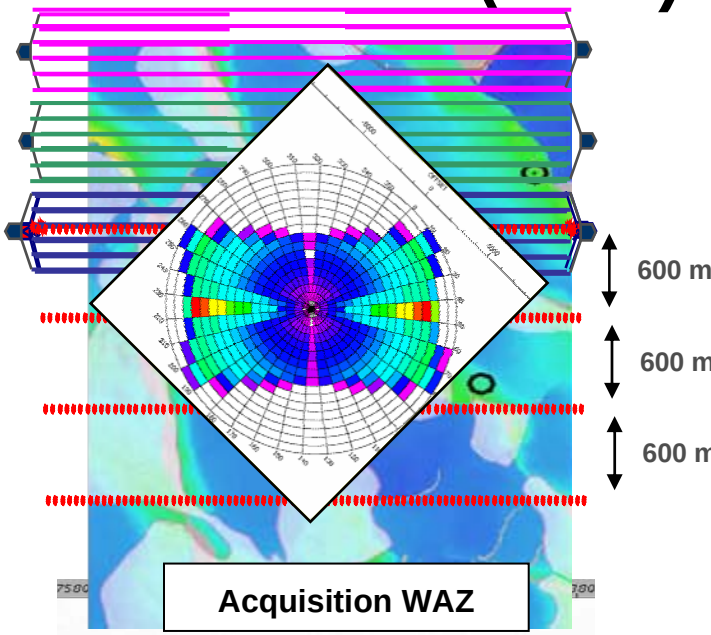
Data acquisition improvement : 3D Wide AZimuth (WAZ)



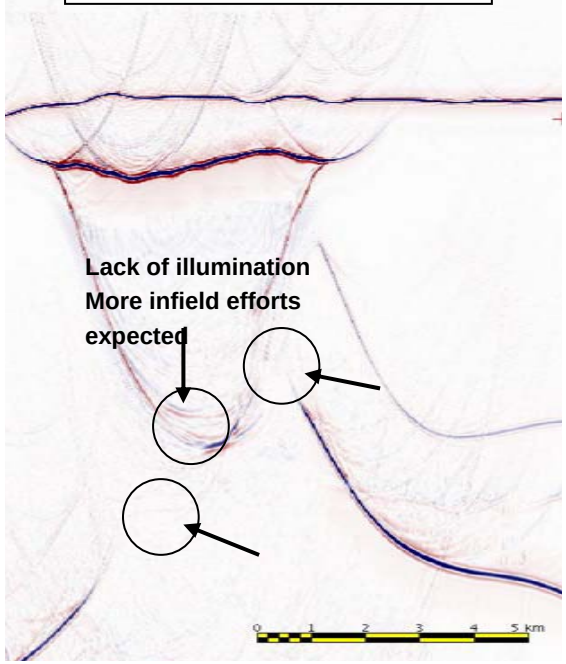
Acquisition standard

Effort à l'acquisition		
standard	WAZ explo	WAZ dévelop.
1 =>	x 5 =>	x 5

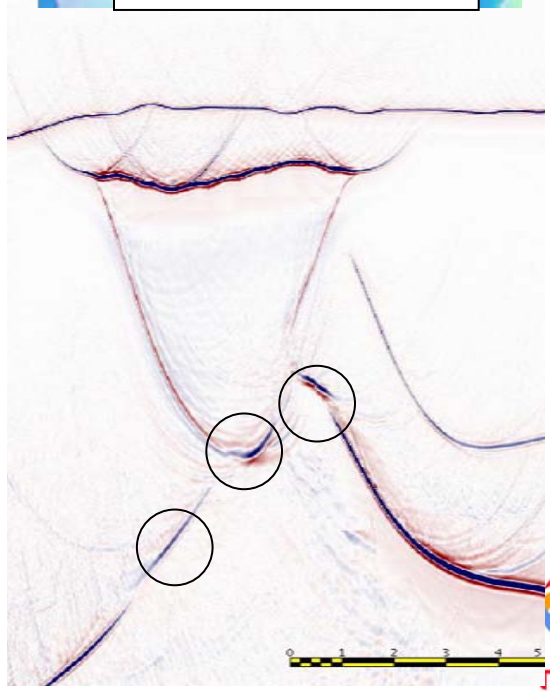




Acquisition WAZ

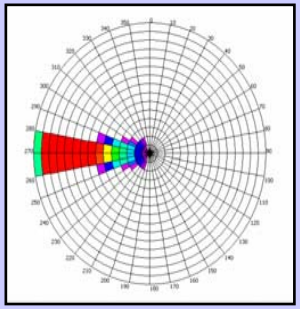
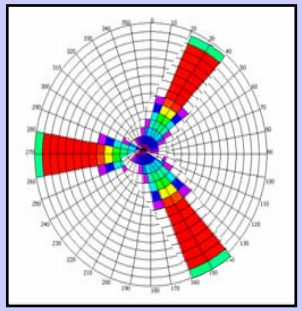
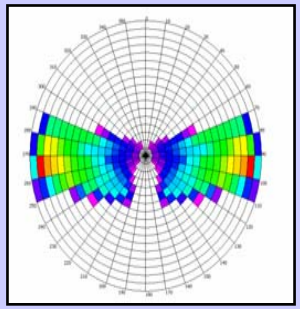
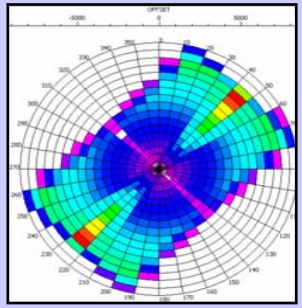
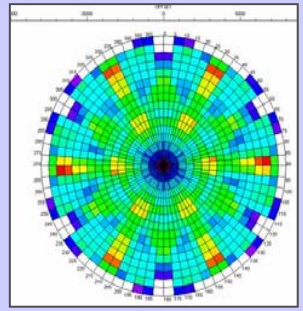
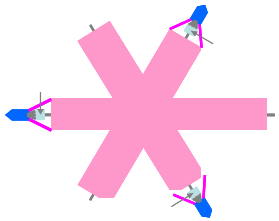
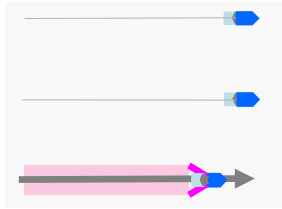
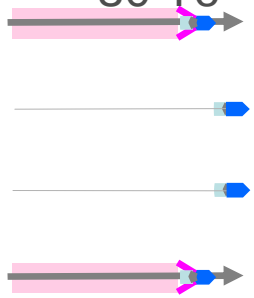
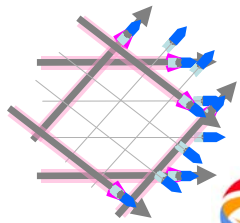


In this example each WAZ line-shot is gathered 6 times (3 times for the 2 ways).
2 ships are involved
In field effort is driven by feasibility studies



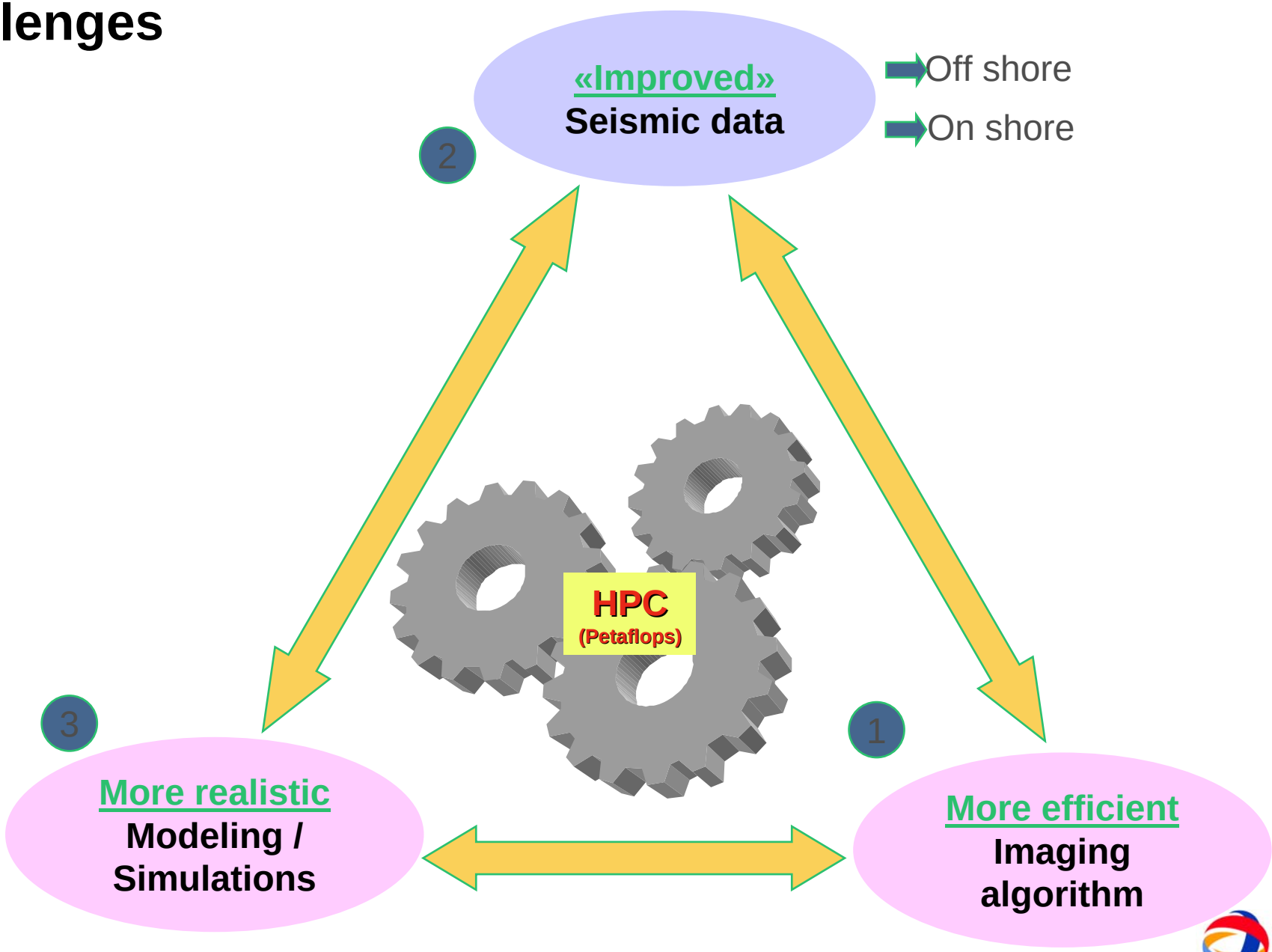
Better Seismic data : off shore

Consequence : more and more data,
Financial impact => detailed feasibility studies (WE modeling in 3D)

	Conventional NAZ	Multi-azimuth MAZ	WAZ Explo 1 Limited Xline offset	WAZ Explo 2 Larger Xline offset	RAZ/Full WAZ Development
					
500 km²					
Cost	7-9 M$	20-25 M$	20-50M$	30-70M$	50-110M$
Volume	5 To	15 To	10 To	30 To	50 To
(data)					

TOTAL

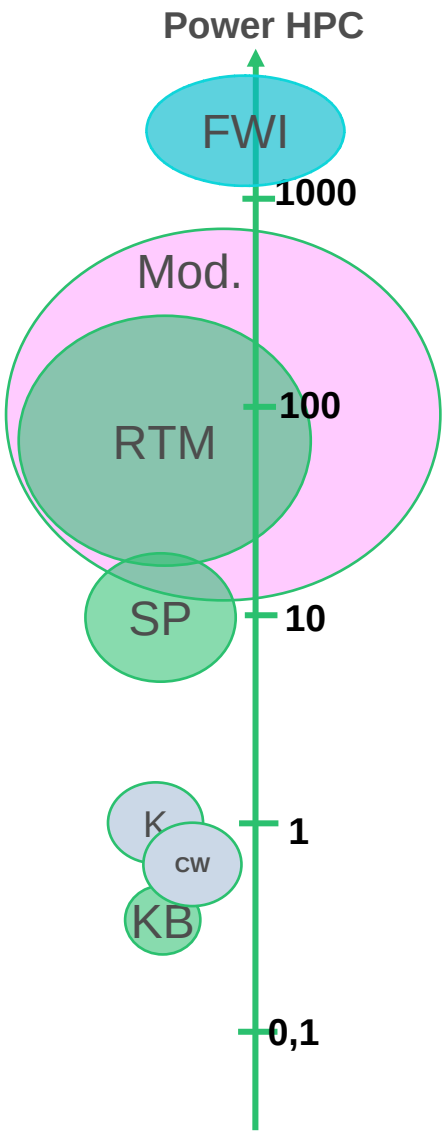
Challenges

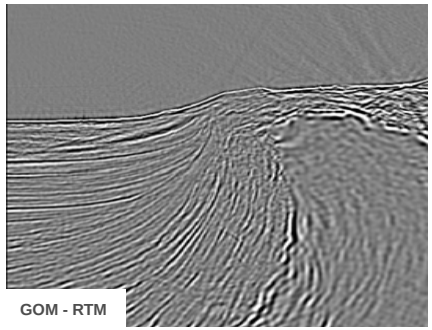


TOTAL

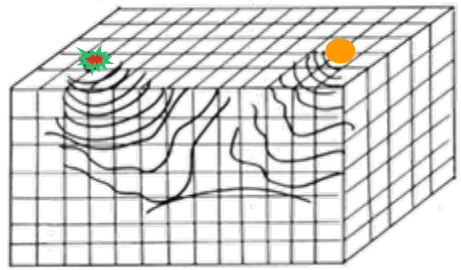
Computing power needs

Imaging algorithm evolution

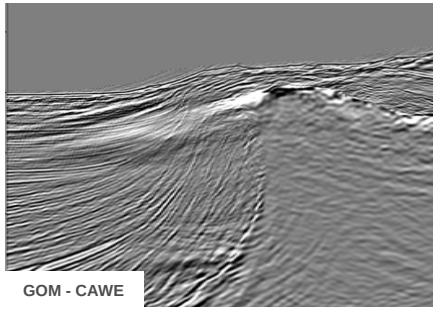



GOM - RTM

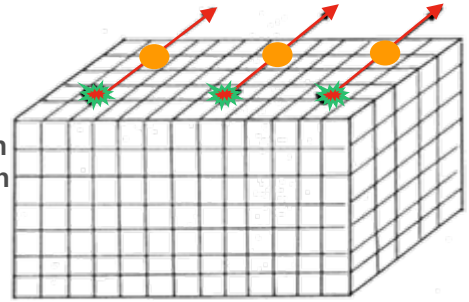
Every azimuth



SP
RTM


GOM - CAWE

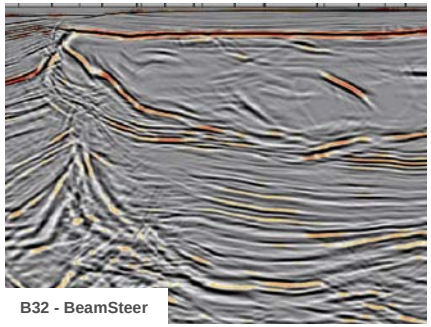
mono azimuth
approximation



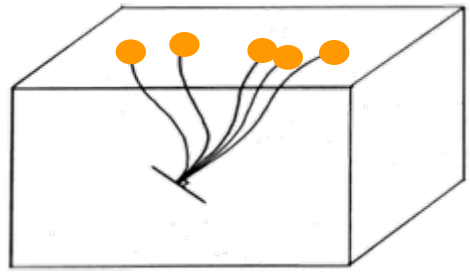
CW

Finite diff

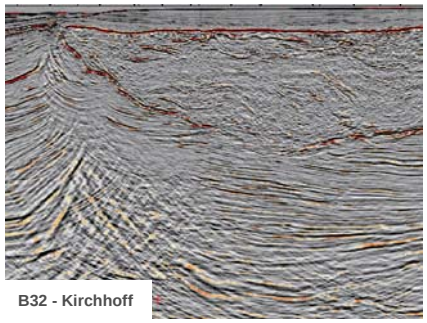
Ray tracing


B32 - BeamSteer

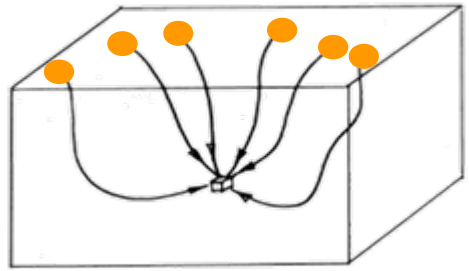
Structural
feature



KB


B32 - Kirchhoff

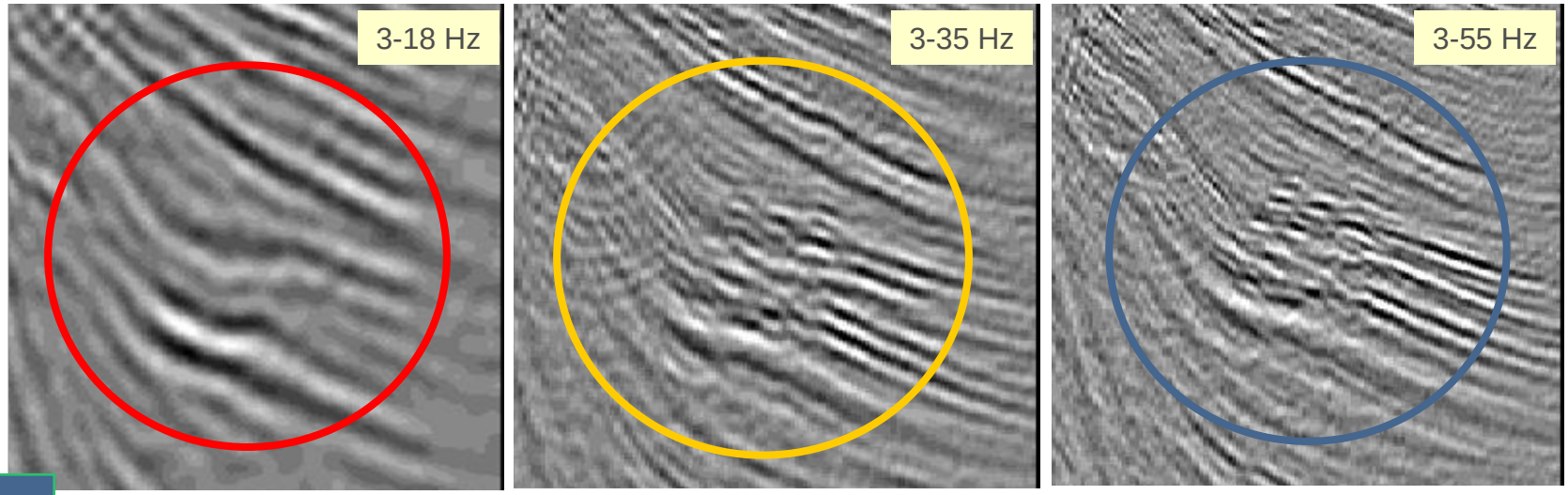
Velocity
model

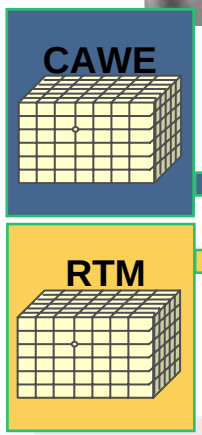


K

Computation time versus seismic bandwidth

- **1000 km² - 3 TeraFlops**





CAWE	1 day	1 X 2 => 2 days*	8 x 3 => 24 days
RTM	150 days	150 x 8 x 2 => 2400 d	150 x 27 x 3 => 12 150 d
	3 - 18 Hz	3 - 35 Hz	3 - 55 Hz
☞	RTM en 8 j => 56 TFlops	900 TFlops	4,5 PFlops

*no change for spatial sampling

Rough order of magnitude depending on parameters and code optimization

TOTAL

Computation power evolution trends

Facilities

- **2 computing centers for imaging**
  - Pau research and production
    - 1900 m² of IT rooms with 1000 m² dedicated for HPC
    - 150 TFlops cumulated power
    - 2.5 Po disk storage and 1.3 Po tape storage
  - Houston research
    - 2 clusters
    - Connection to Pau facility
- **Teams**
  - Integrated geophysics, research and IT

TOTAL

2007 project for power purchase

- **Technical constraints**
  - Shot Point in 7 days over 250000 shots
- **R&D constraints to anticipate for future developments**
  - Minimal bandwidth for interconnect
  - Memory: 20 To
  - Storage with sustained bandwidth of 10 Go/s
- **Environment**
  - Electrical consumption limited to 600 kW
  - Building organization
- **Codes**
  - For production (main purpose)
  - For research (future anticipation)
- **Duration**
  - 12 to 18 month between decision and production

TOTAL

Why MPP ?

- **Reliability and performances on very large configurations**
  - More than 10.000 cores, 20TB memory
  - Mastering components number compared to a cluster solution
- **Impact on footprint**
  - Density : less than 30 racks (included storage)
  - Only 400 kW for 122 TFlops
- **Interconnect power**
- **Our codes take advantage from this architecture**
  - Scaling
  - Use of interconnect
- **Accelerating technology may lead us to revisit those choices**

TOTAL

Next steps

- **R&D**
  - Multiple parallel projects
    - Algorithms (Full Waveform Inversion)
    - New architectures (cell, graphical power units)
    - Programming models
  - Computation power for research
    - Cluster for scaling (currently 512 cores)
    - GPU Cluster
    - Vector Computer
    - Cell blades
- **A constantly evolving facility**
  - Anticipating needs in terms of energy delivery and cold production
  - Minimization of energetic impact
    - At Pau facility, heat from machine rooms is used to producing hot water for the site when external temperature stays above 4°C.

TOTAL

Conclusion

- **Computation needs for seismic processing is nearly not bounded!**
  - Improvement of our algorithms (Full Waveform Inversion, …)
  - Size of spatial sampling cells (frequency areas, …)
  - Seismic acquisition parameters (Azimuth width, distance between receivers, …)

Available computing power is the main driver

TOTAL