SEG: Bridging Technology & People

SEG Board Special Lecture Series

SEG董事特别名誉讲座

SEG Student Chapters
National Central University

April 29, 2014

www.seg.org/membership



Alfred L. Liaw 廖良基
SEG Board of Director
Anadarko Petroleum Corporation

Society of Exploration Geophysicists
The international society of applied geophysics

SEG is People:

33,000 members

138 countries

52 affiliated societies

270 student chapters

33,000 名会员

138 个国家

52 个下属分会

270 个学生分会



Presentation Outline
报告提纲

- **Recent advances in sub-salt imaging**
  盐丘下方成像的最新进展
- **Broadband seismology**
  宽带地震学
- **3D seismology for unconventional resources development**
  非常规能源开发的三维地震
- **Summaries**
  总结

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Four Decades of Improvements in Marine Seismic Acquisition
海洋地震采集近40年的发展

- From 2D to 3D to 4D 从二维到三维到四维
- More channels, longer and closer towed streamers 更多道，更长更密集的拖曳电缆
- Wider azimuthal coverage 宽方位角覆盖
- Bigger and better tuned sources 更大, 性能更好的调谐震源
- Quieter solid streamer 消声固体电缆
- Advanced navigation and positioning 先进的导航和定位
- Improved recording instrument (low frequency) 改进的记录仪（低频）



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3-D Marine Seismic Survey
三维海上地震勘探

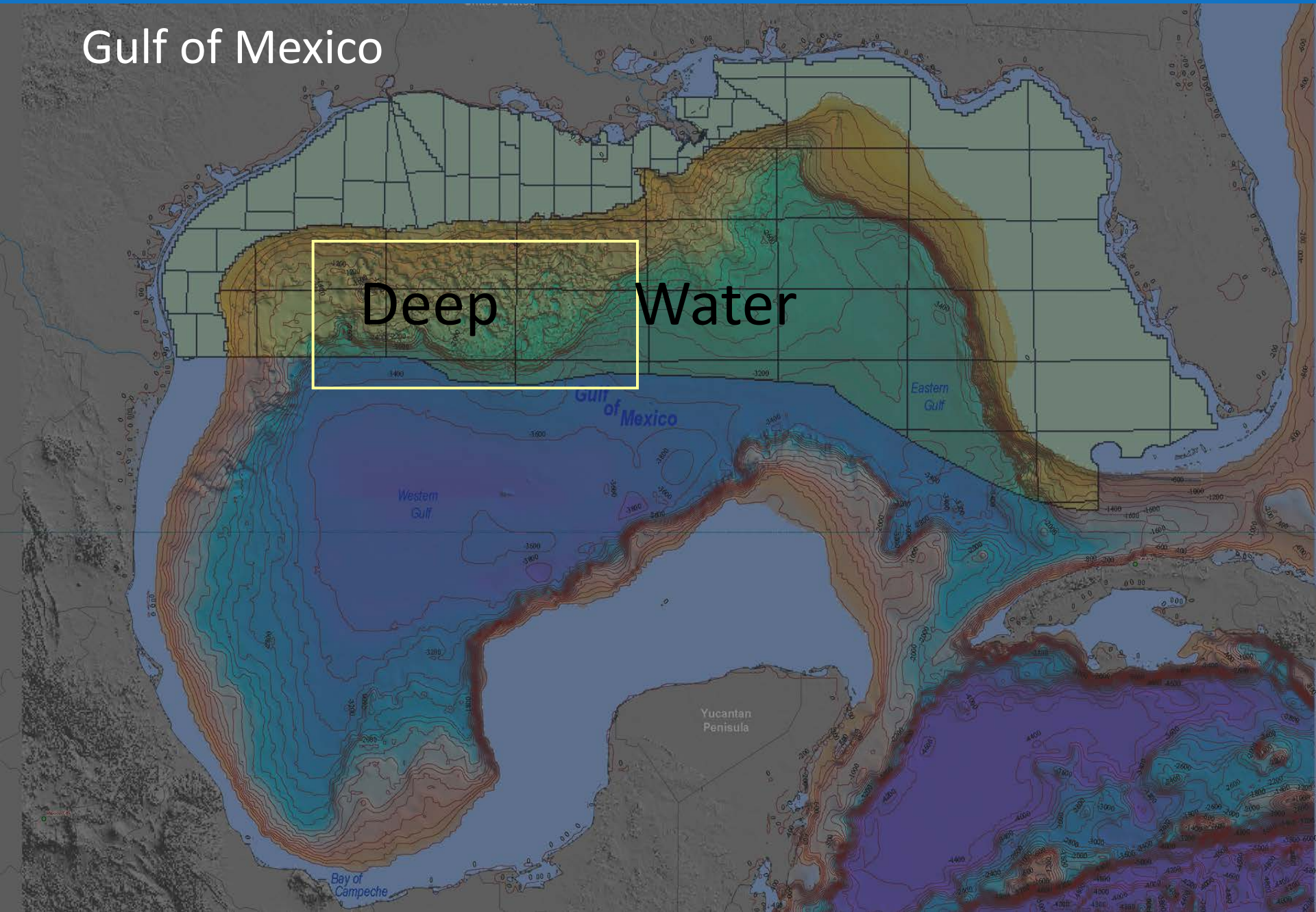
- Started with two streamers, two sources in the 90's. **在90年代用的是两个电缆与两个震源**
- Maximum number of streamers currently is ~18. **现在最大的电缆数为18**
- Most common configuration is 6-10 streamers of 6-8 kms. in length.
  最常见的配置是每6-8公里6-10个电缆



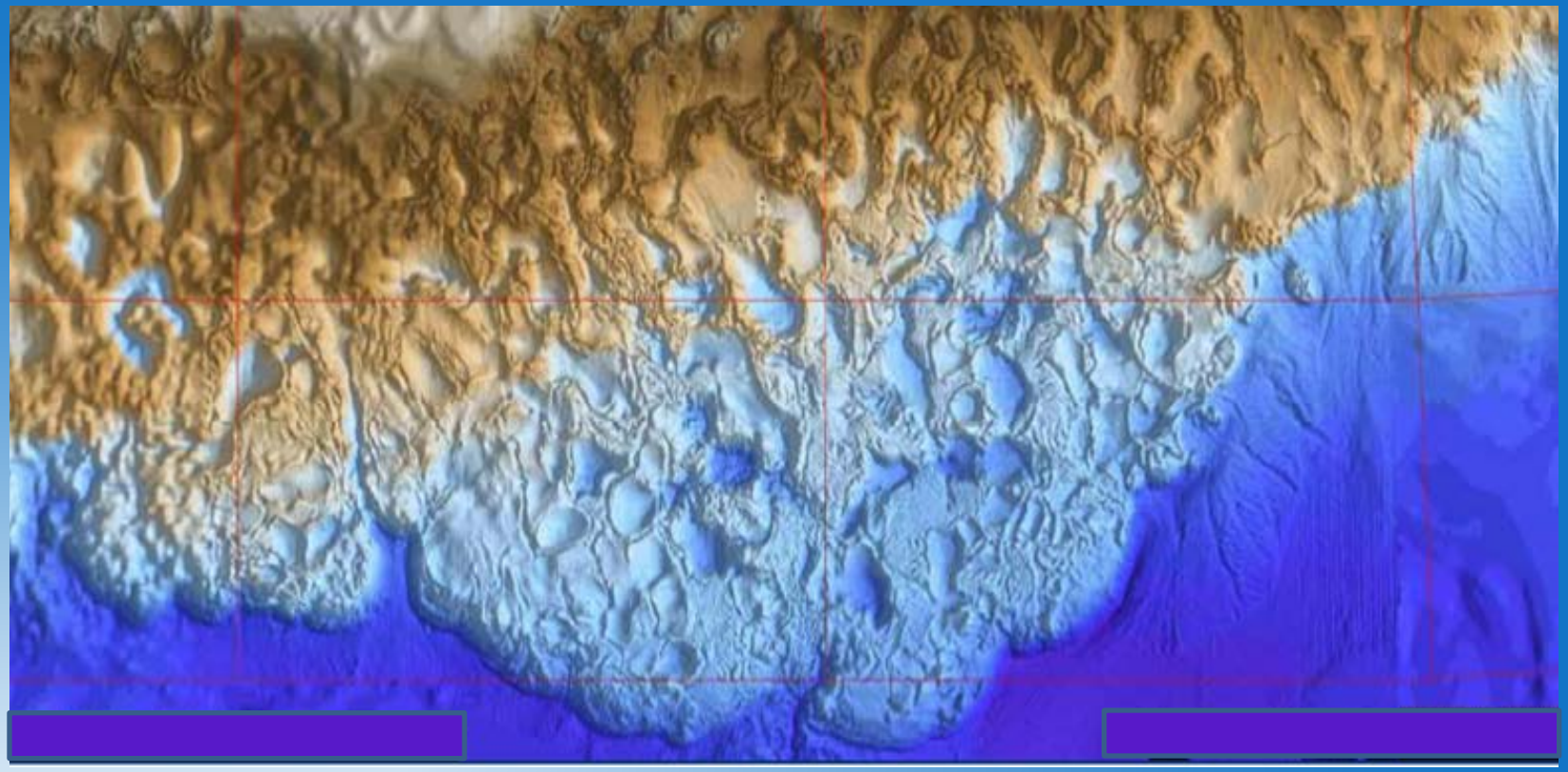


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Gulf of Mexico



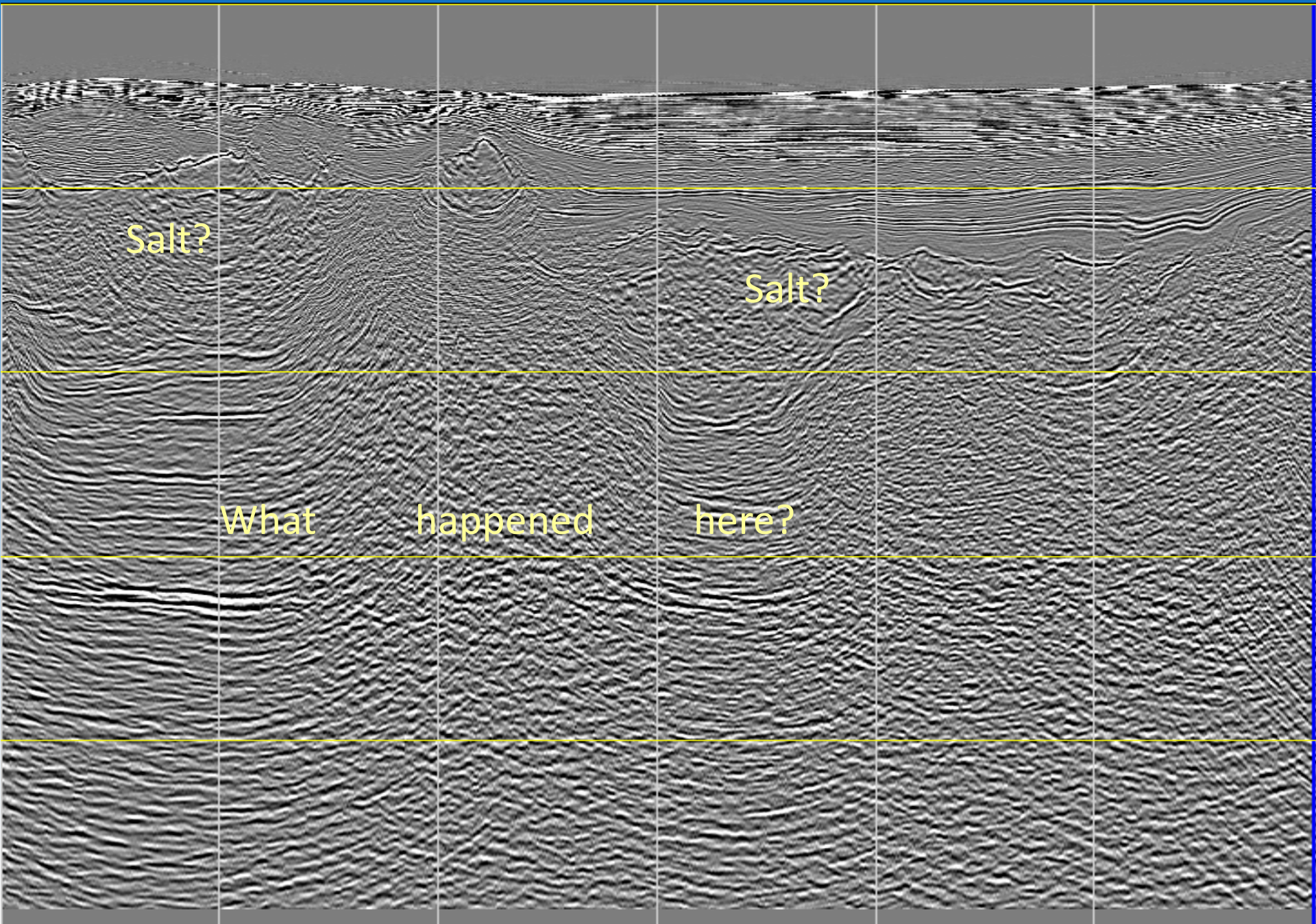
Gulf of Mexico Salt Basin



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NAZ PSDM WEM



SEG: Peoples Sharing Technologies

- **Annual Meeting is largest meeting of geoscientists in the world!**
  - 11,019 attendees
  - 394 exhibitors
  - 992 presentations
  - 176 poster sessions
  - 192 e-posters
  - 1,451 booths

SEG HOUSTON 2013

Society of Exploration Geophysicists International Exposition and 83rd Annual Meeting
George R. Brown Convention Center • 22–27 September 2013 • Houston, Texas USA



SEG Houston 2013

Marine Multi-Azimuth and Wide-Azimuth Seismic

SS 2.1 (2886-2890)
Key aspects of multiazimuth acquisition and processing
James Keggin, Ted Manning, and Walter Rietveld, BP Exploration Operating Co; Chris Page*, Eivind Fromyr, and Roald van Borselen, PGS Marine Geophysical

SS 2.2 (2891-2895)
Multiazimuth towed streamer 3D seismic in the Nile Delta, Egypt
Jim Keggin*, Mark Benson, Walter Rietveld, Ted Manning, Brian Barley, Peter Cook, and Ed Jones BP; Martin Widmaier, Tom Wolden, and Chris Page, PGS

SS 2.3 (2896-2900)
Using 3D finite-difference modeling to design wide-azimuth surveys for improved subsalt imaging
Carl Regone*, BP

SS 2.4 (2901-2904)
Implementing a wide-azimuth towed streamer field trial: The what, why, and mostly how of WATS in southern Green Canyon
Ian M. Threadgold* and Kristin Zembeck-England, BP; Per Gunnar Aas, Geophysical Safety Resources; Philip M. Fontana and Damian Hite, Veritas; William E. Boone, consulting geophysicist

SS 2.5 (2905-2909)
Wide-azimuth streamer imaging of mad dog: Have we solved the subsalt imaging problem?
Scott Michell*, Elena Shoshitaishvili, Dean Chergotis, John Sharp, and John Etgen, BP

SS 2.6 (2910-2914)
Wide-azimuth streamer acquisition for Gulf of Mexico subsalt imaging
Chris Corcoran*, Colin Perkins, David Lee, and Paul Cattermole, Shell E&P; Richard Cook, Shell Int'l E&P; Nick Moldoveanu, WesternGeco

SS 2.7 (2915-2919)
Marine survey design for rich-azimuth seismic using surface streamers
M. S. Howard*, BHP Billiton; N. Moldoveanu, WesternGeco

SS 2.8 (2920-2924)
Design and operation of a deep water, wide-azimuth node seismic survey
Allan A. Ross* and Gerard Beaudoin, BP

Gulf of Mexico

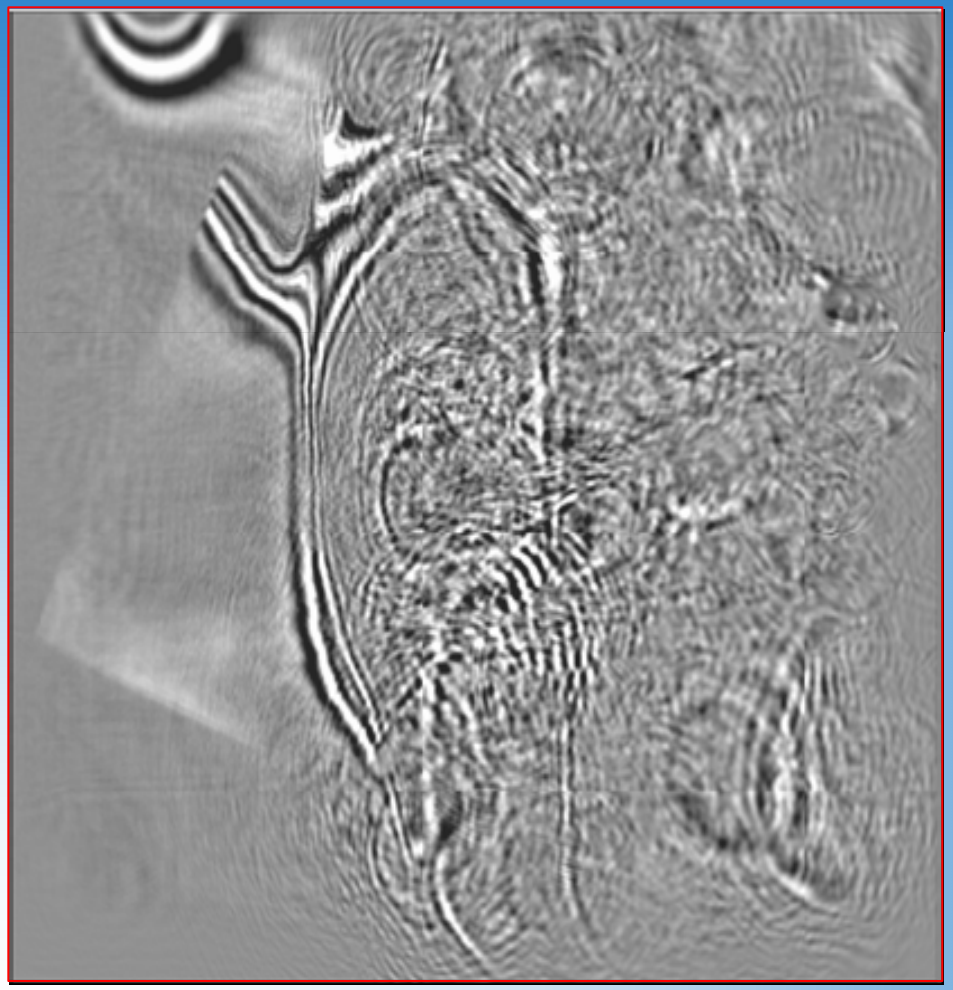


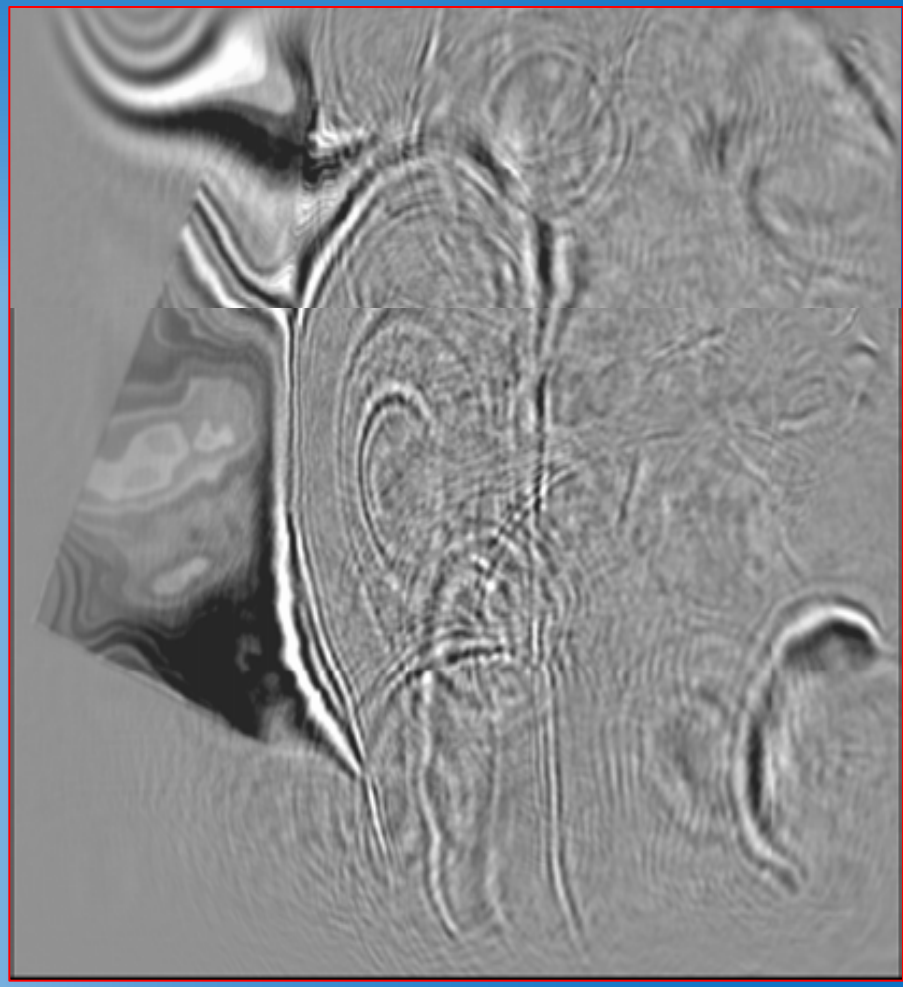
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BP Atlantis Synthetic Models

Narrow Azimuth

Wide Azimuth Tile 1 排列板

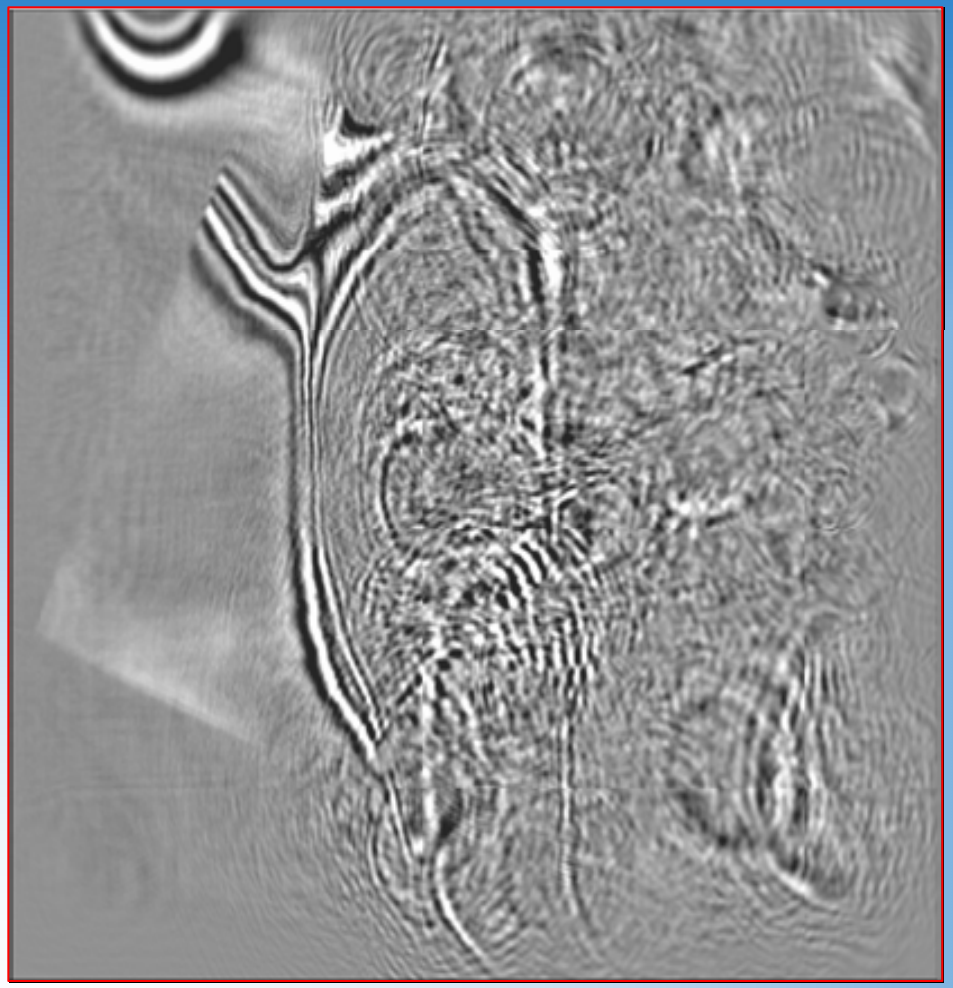




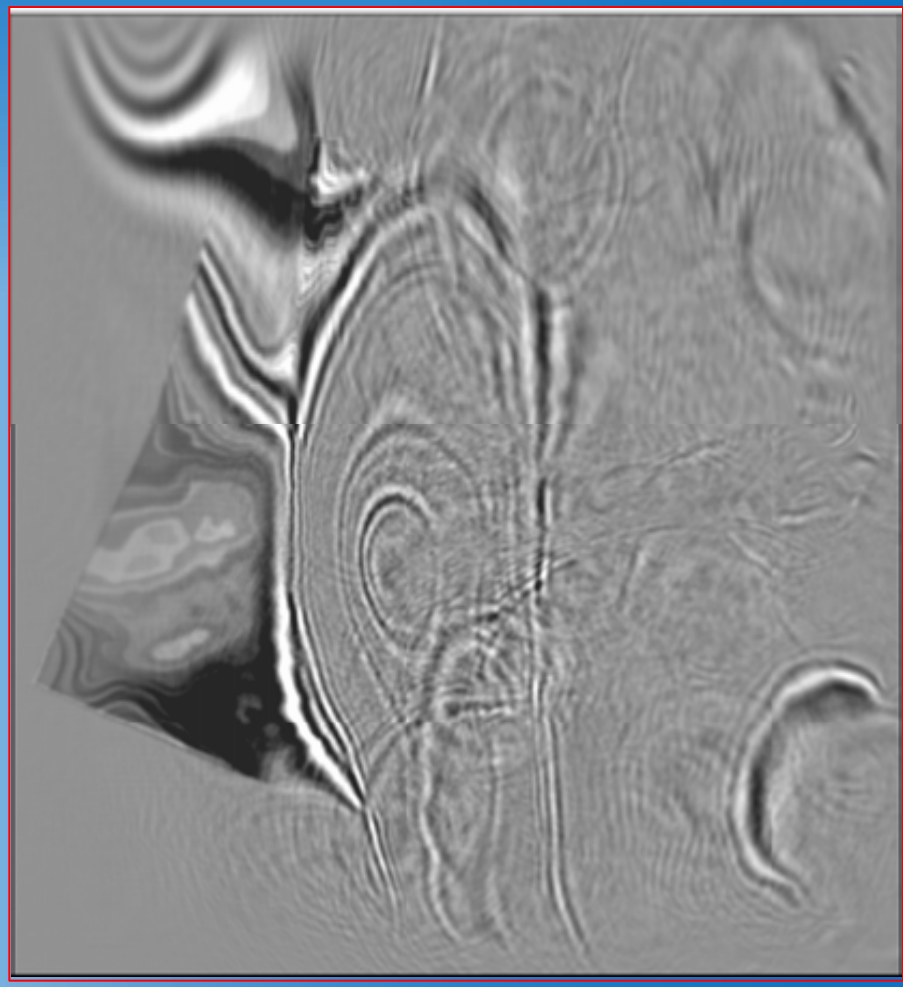
Regone 2006

BP Atlantis Synthetic Models

Narrow Azimuth



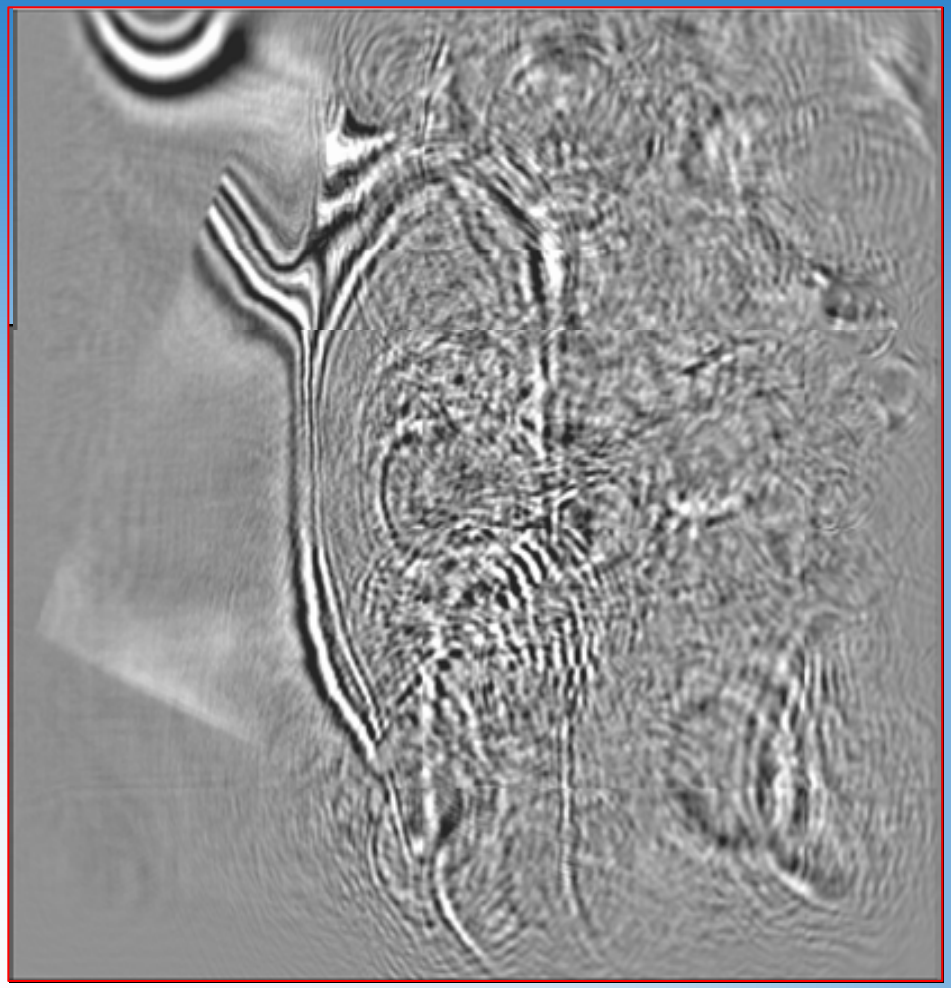
Wide Azimuth Tile 1-2



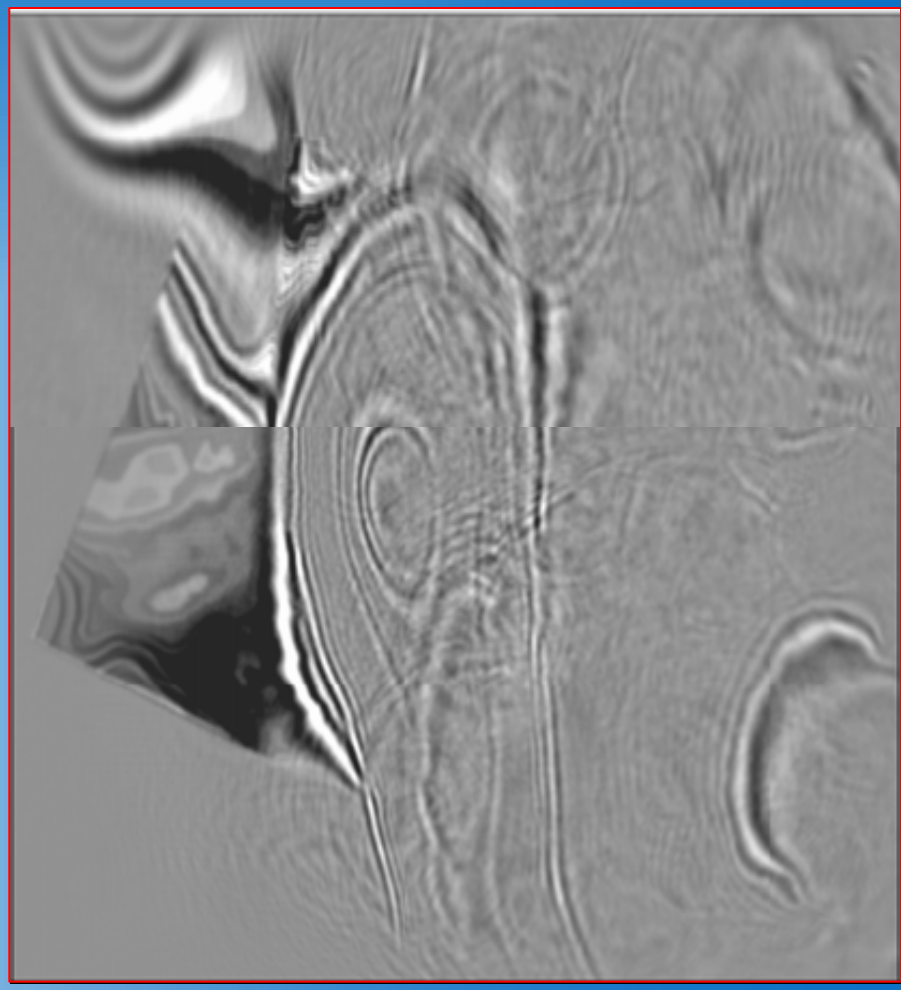
Regone 2006

BP Atlantis Synthetic Models

Narrow Azimuth



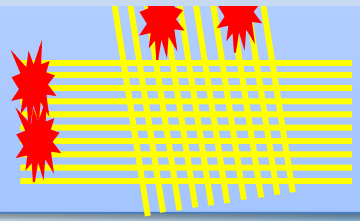
Wide Azimuth Tile 1-4



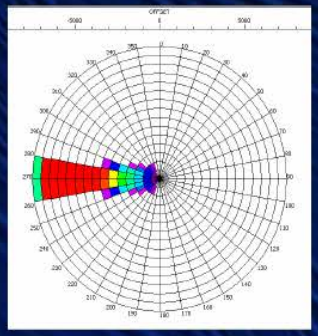
Regone 2006

Marine Streamer Acquisition Styles
海洋拖缆采集方式

- **Wide Azimuth Acquisition**
  宽方位采集
  - **Improved illumination**
    提高照明度
  - **Reduced free surface multiple noise**
    压制多次波

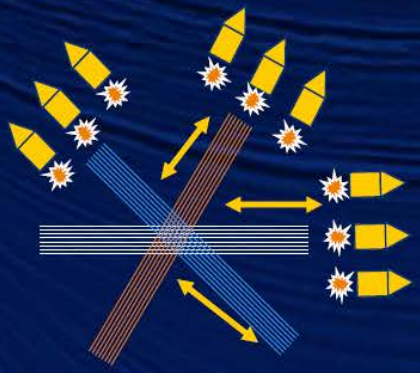
Rich Azimuth (RAZ) 丰富的方位		excellent 非常好	5-6 x

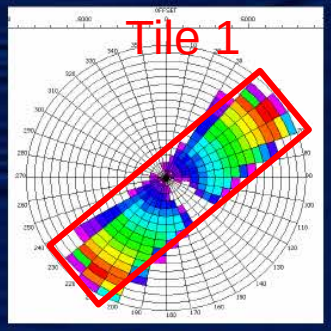
Acquisition Geometries 采集观测系统



Narrow Azimuth

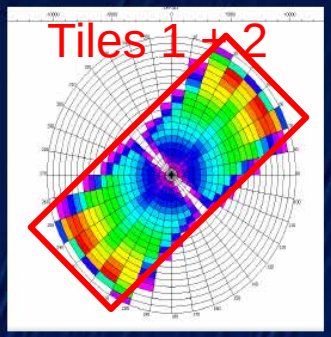
窄方位角





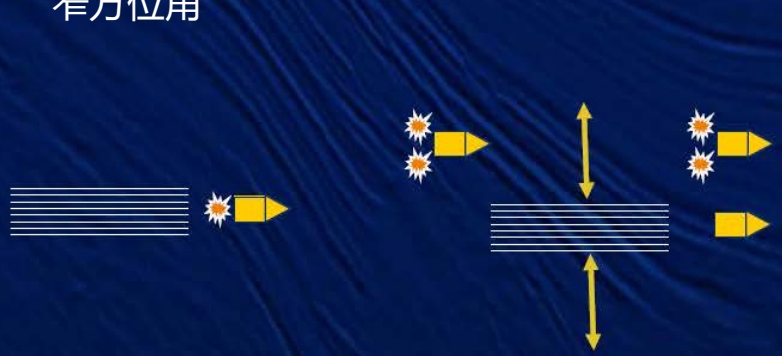
Phase 1 Wide Azimuth

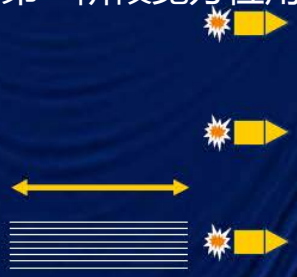
第一阶段宽方位角

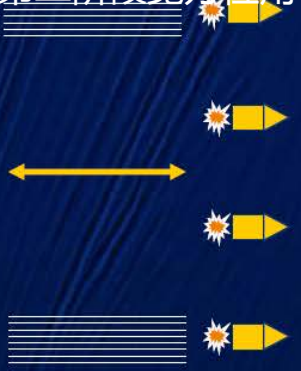


Phase 2 Wide Azimuth

第二阶段宽方位角









Opportunities Uncovered. Results Delivered.

WesternGeco

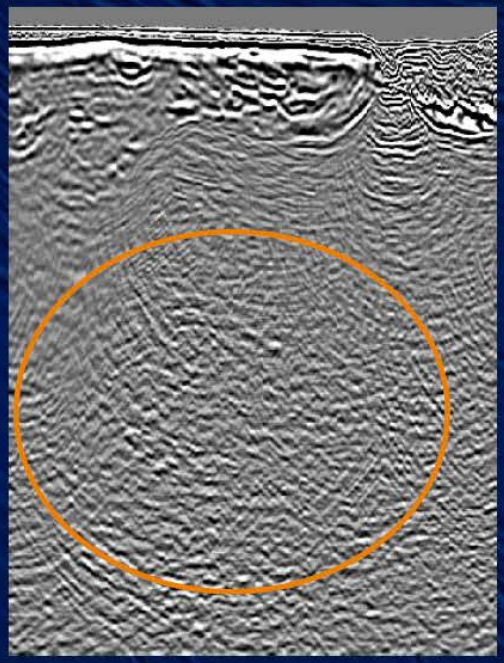
Society of Exploration Geophysicists

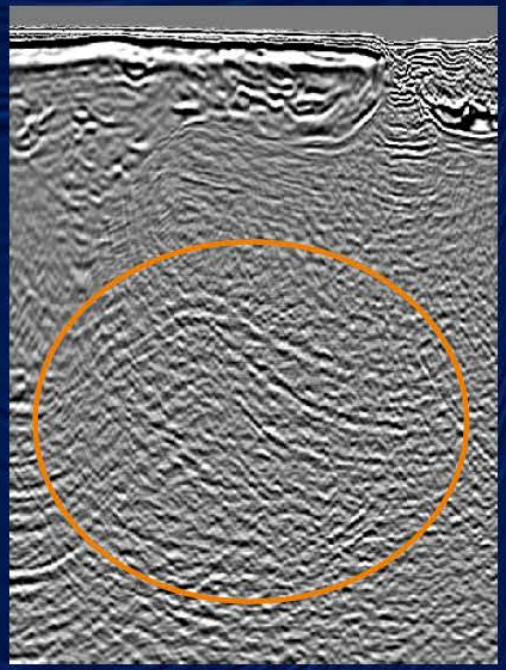
The international society of applied geophysics

Wide azimuth acquisition design comparisons
宽方位采集方案对比

Recording vessel sources only

All sources









NAZ

2x4 WAZ

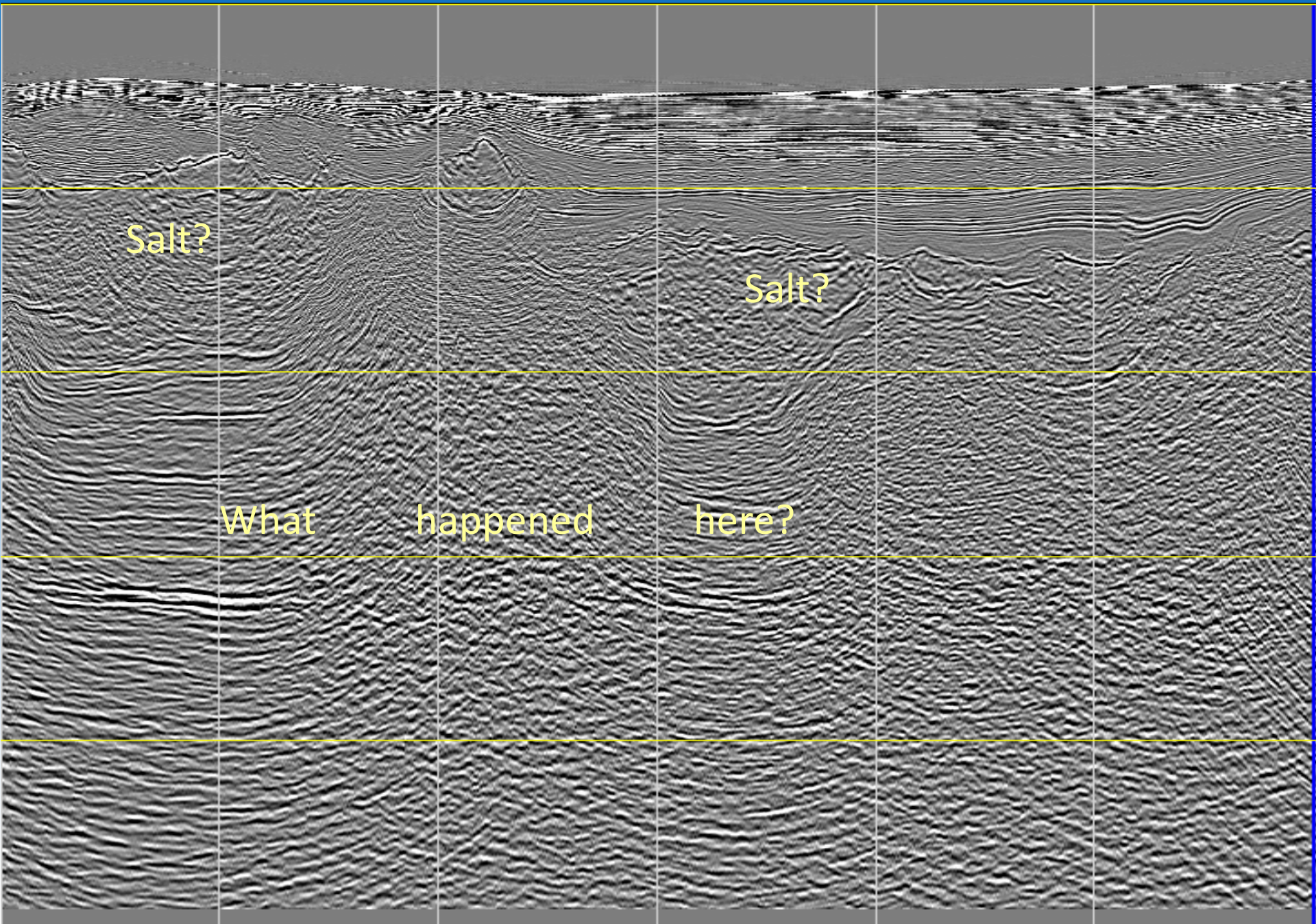
Opportunities Uncovered. Results Delivered.

WesternGeco

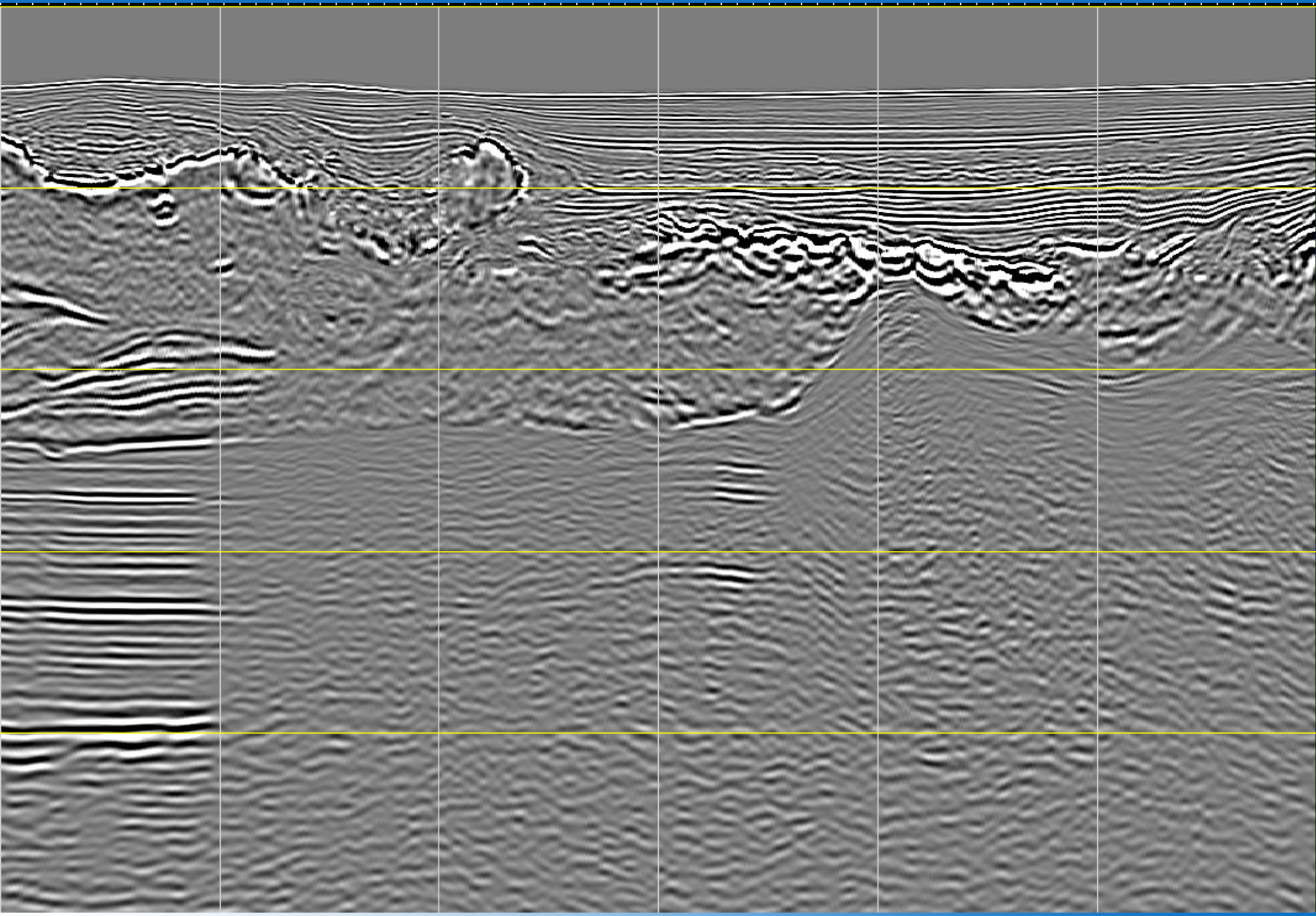
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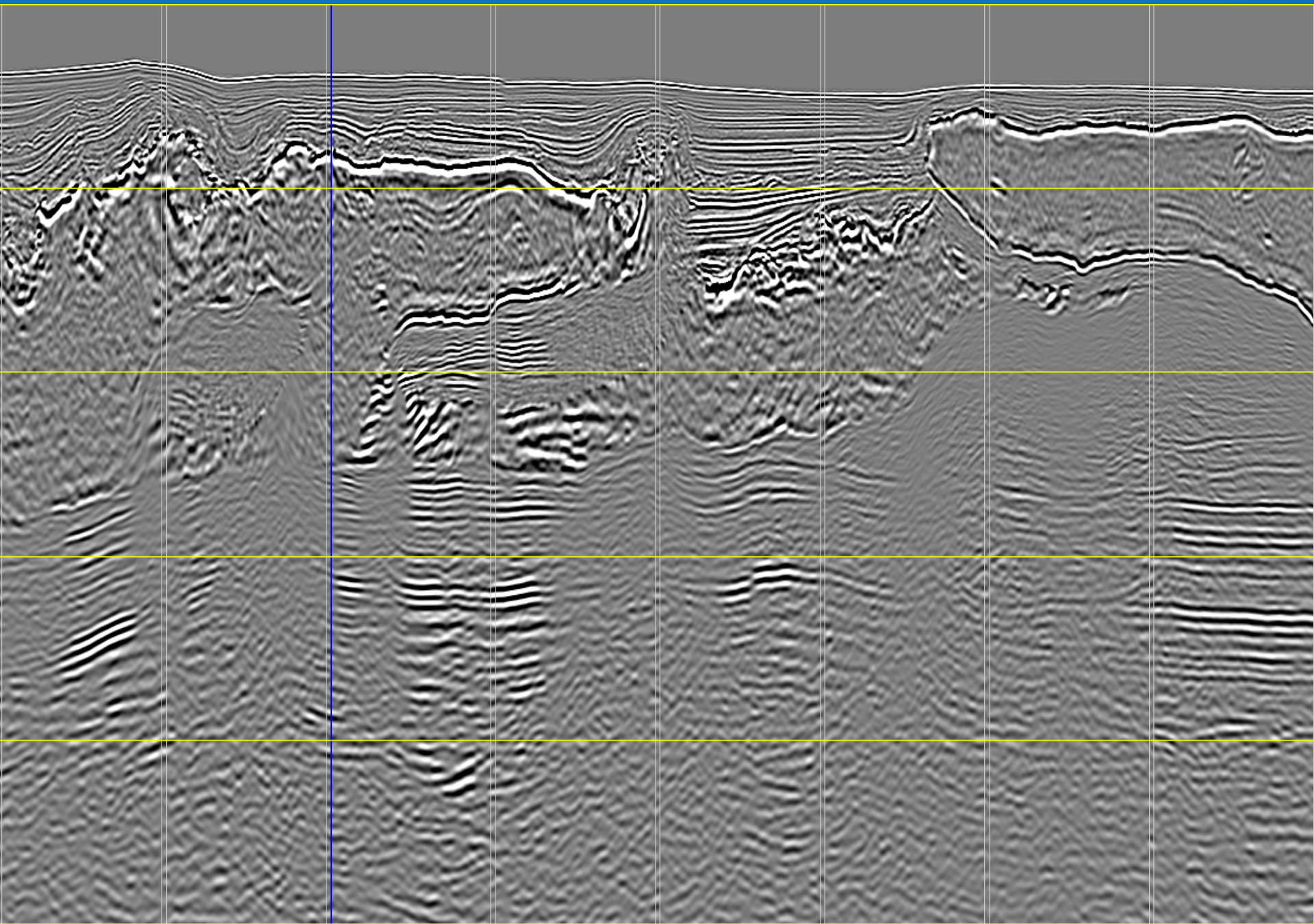
NAZ PSDM WEM



WAZ RTM (not final)



WAZ RTM



Model Study (Subsalt Imaging – The RAZ/WAZ experience)

模型研究（盐丘下方成像 – 采用大方位角/宽方位角）

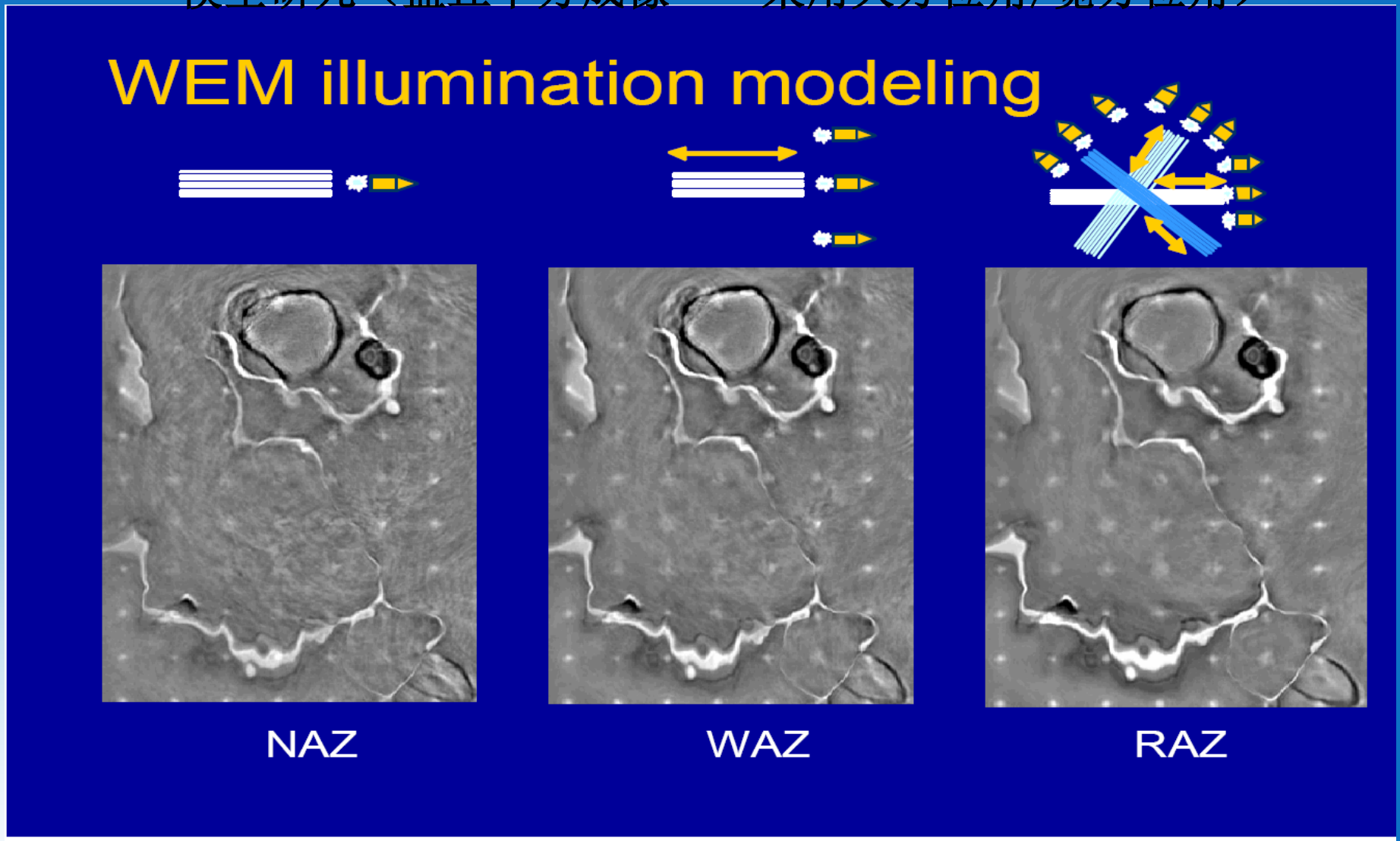


Figure 2: Modeled data migrations using simulated narrow, wide and rich azimuth acquisition geometries. Notice the improvement in resolution especially of the embedded grid of spheres from NAZ to WAZ to RAZ.

图2： 由窄、宽和丰富方位采集观测系统得到的模型数据偏移结果。从图中可看到分辨率逐渐提高，尤其是嵌入的球形网格处。

Kapoor, et al; SEG 2007 Annual Meeting

Multiple Attenuation
多次波衰减

- **Better 3D multiple model by WAZ survey**
  由宽方位角资料能得到更好的三维多次波模型
- **Enhanced by multiple tiles of data coverage**
  通过多次波数据叠加来改进
- **SRME (Surface Related Multiple Elimination)**
  表面多次波衰减

Depth Imaging Technology
深度成像技术

- **Wave Equation Migration**

  波动方程偏移
- **Kirchhoff Migration**

  克希霍夫偏移
- **Beam Migration**

  射线束偏移
- **Reversed Time Migration (RTM)**

  逆时偏移（RTM）

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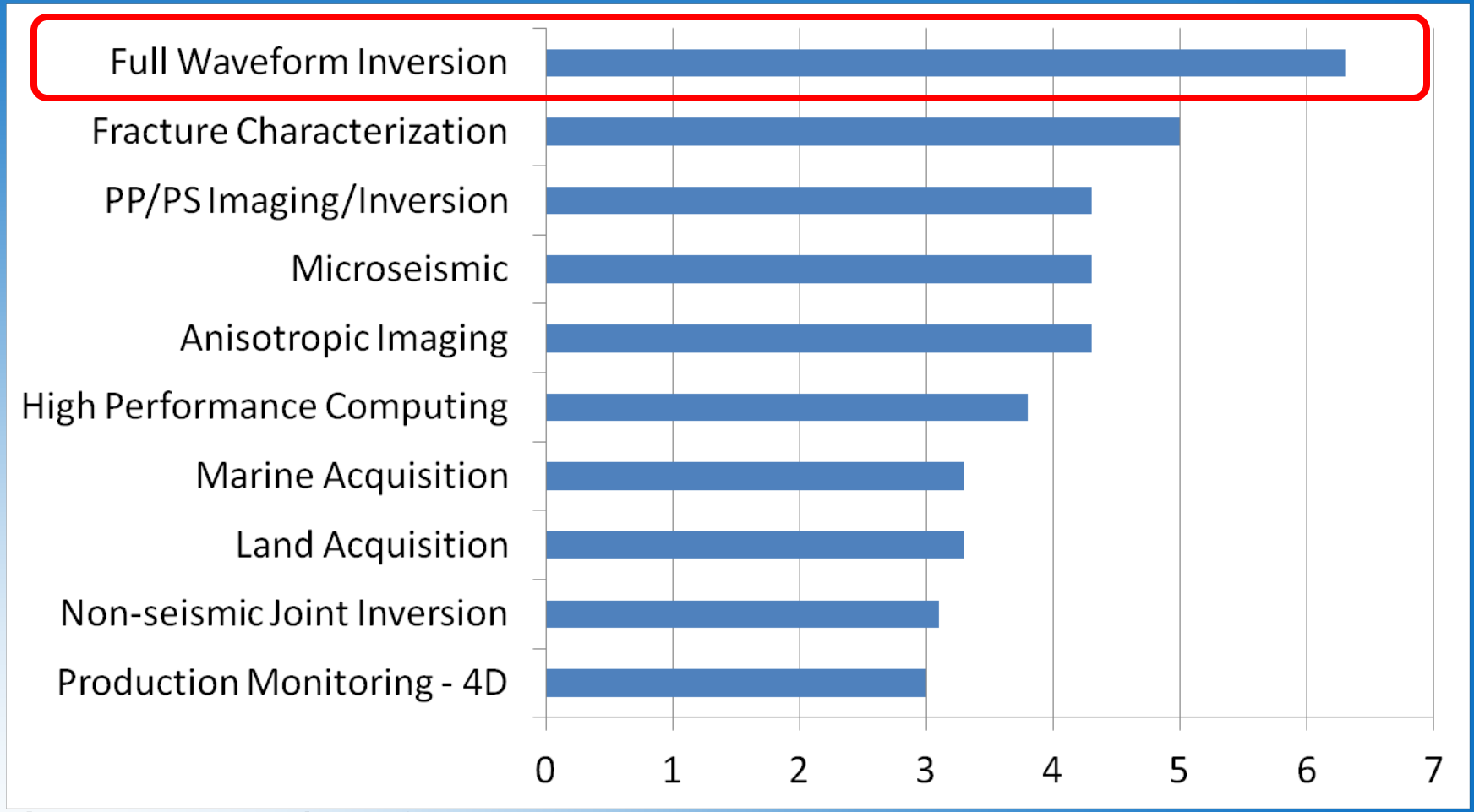
Velocity Model Building
速度建模

- **Semblance Velocity Analysis**
  表层速度分析
- **Layered Tomographic Inversion**
  层状 层析反演
- **Grid-base Tomographic Inversion**
  网格 层析反演
- **Full Waveform Inversion**
  全波形反演



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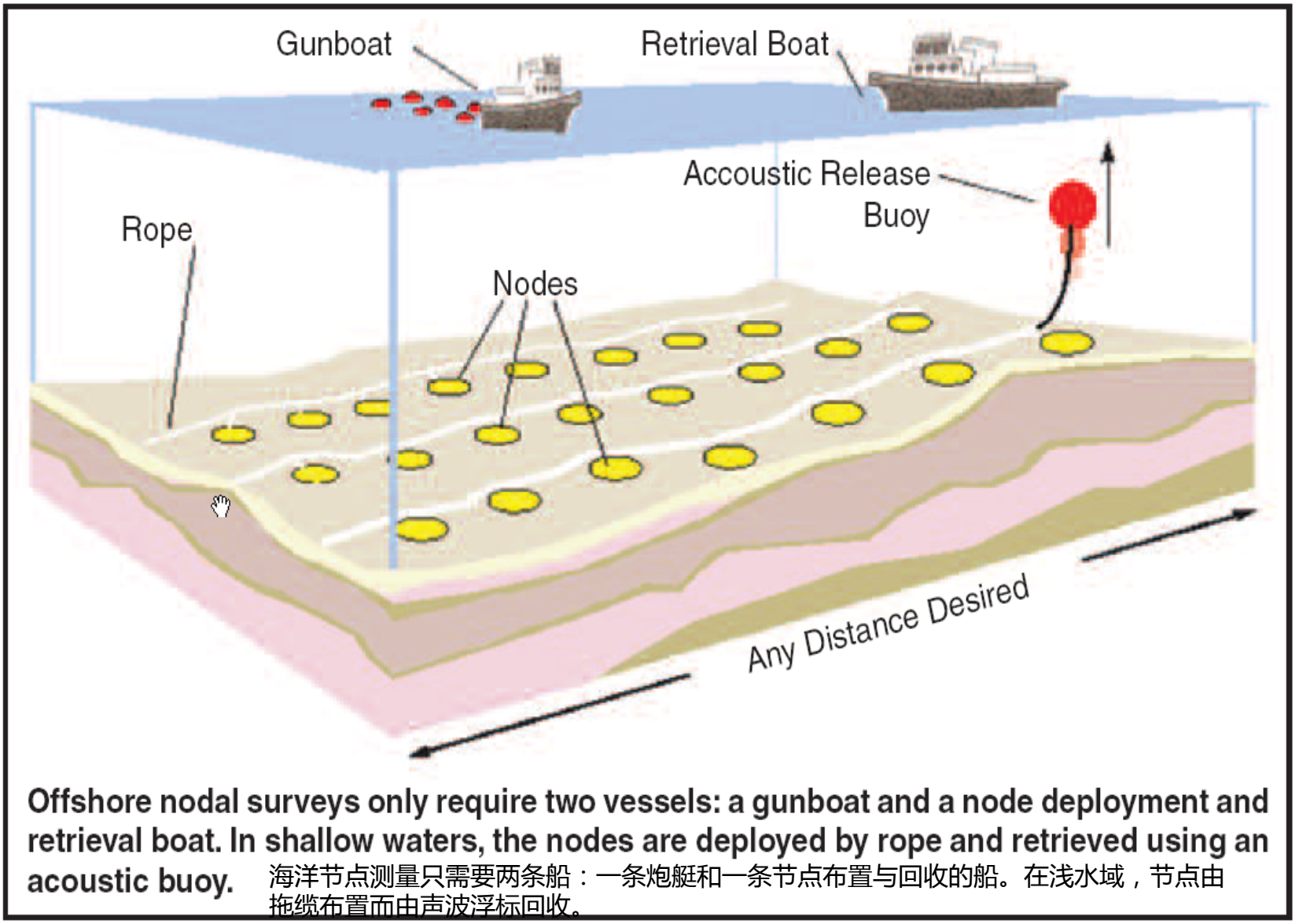
SEG Research Committee Priorities
SEG研究委员会研究比例分布



Full Waveform Inversion (FWI) 全波形反演

- Extra long offset records 扩大偏移距记录
- Low frequency signal 低频信号
- Elastic vs. acoustic seismic signals
  弹性vs. 声波地震信号
- Multiples & diffractions 多次波与绕射波
- Convergent criteria 收敛准则
- An accurate long wavelength starting velocity model 几近正確啟始速度模型

Ocean Bottom Nodal Survey (OBN) 海洋结点 采集

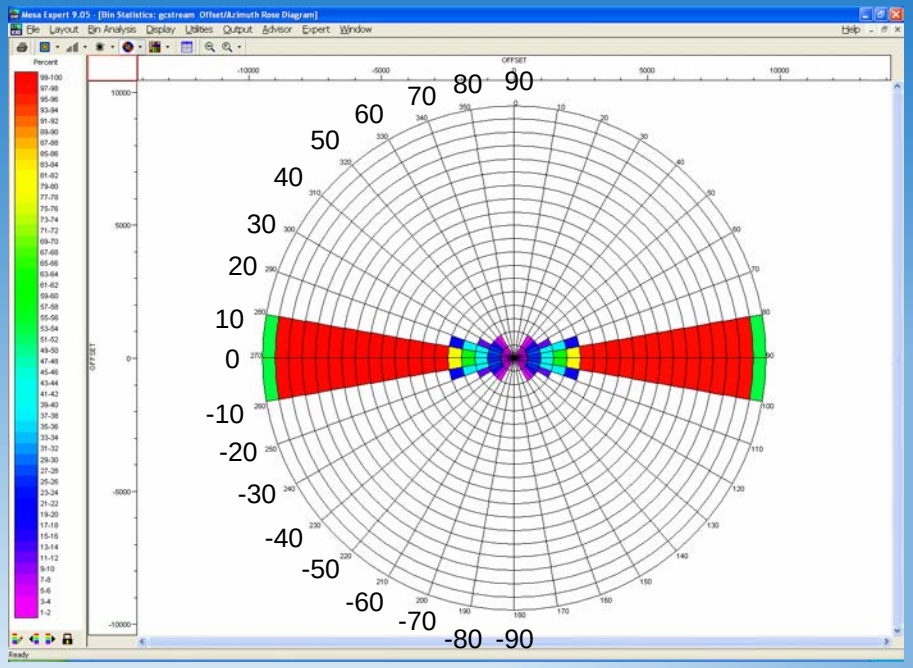


Offshore nodal surveys only require two vessels: a gunboat and a node deployment and retrieval boat. In shallow waters, the nodes are deployed by rope and retrieved using an acoustic buoy.

海洋节点测量只需要两条船：一条炮艇和一条节点布置与回收的船。在浅水域，节点由拖缆布置而由声波浮标回收。

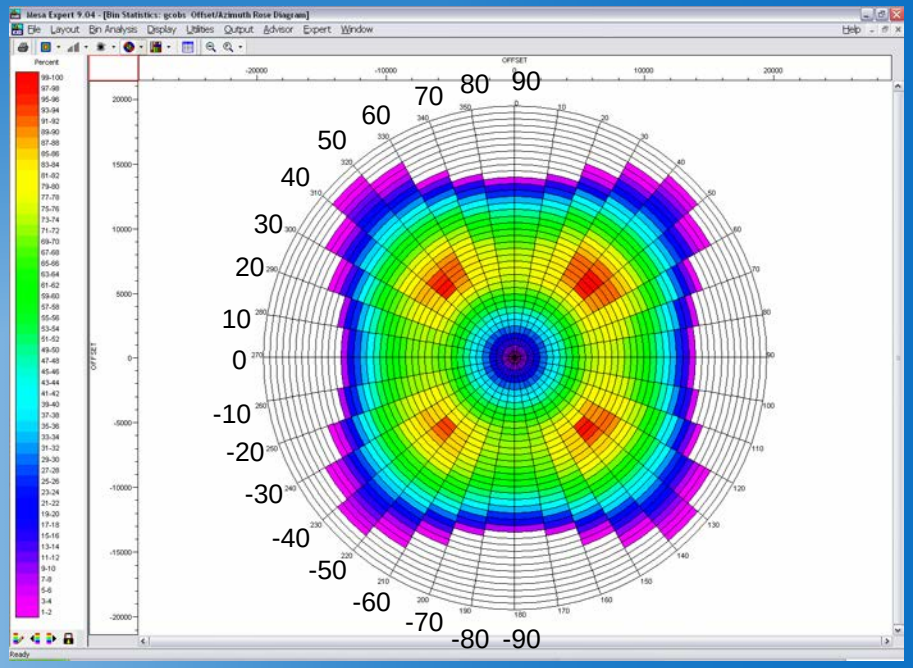
Azimuth Distribution – Conventional vs. OBN
方位角分布—常规的与OBN比较

East-West Streamer 东西向电缆



Limited Azimuth
有限的方位角

OBN

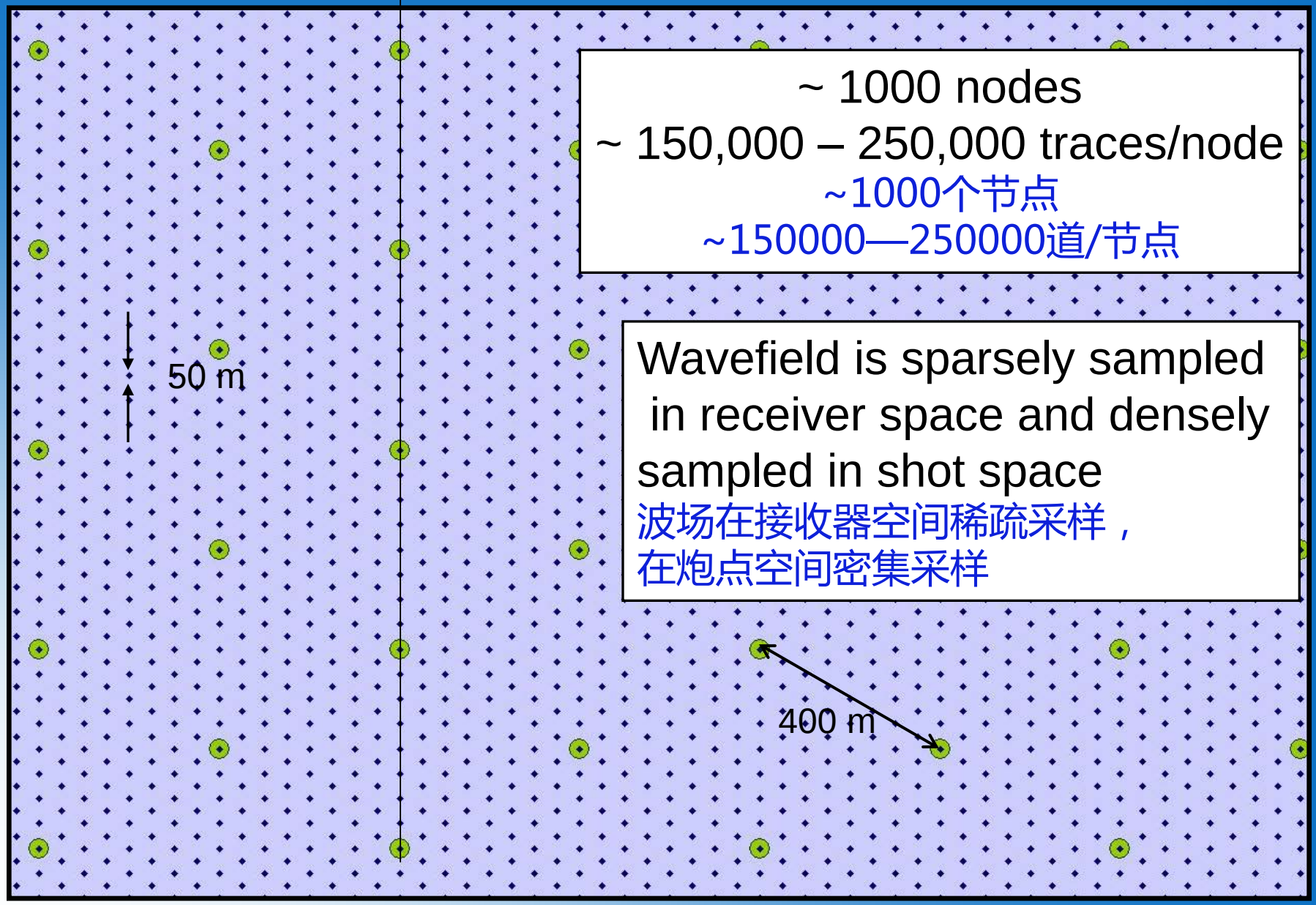


Full Azimuth
全方位角

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Typical Deep Water OBN Geometry

典型深水OBN观测系统



Comparison of Imaged Synthetic Seismic Data "Acquired" over Atlantis
NATS (Narrow Azimuth Towed Streamer) vs. NODES (OBN)

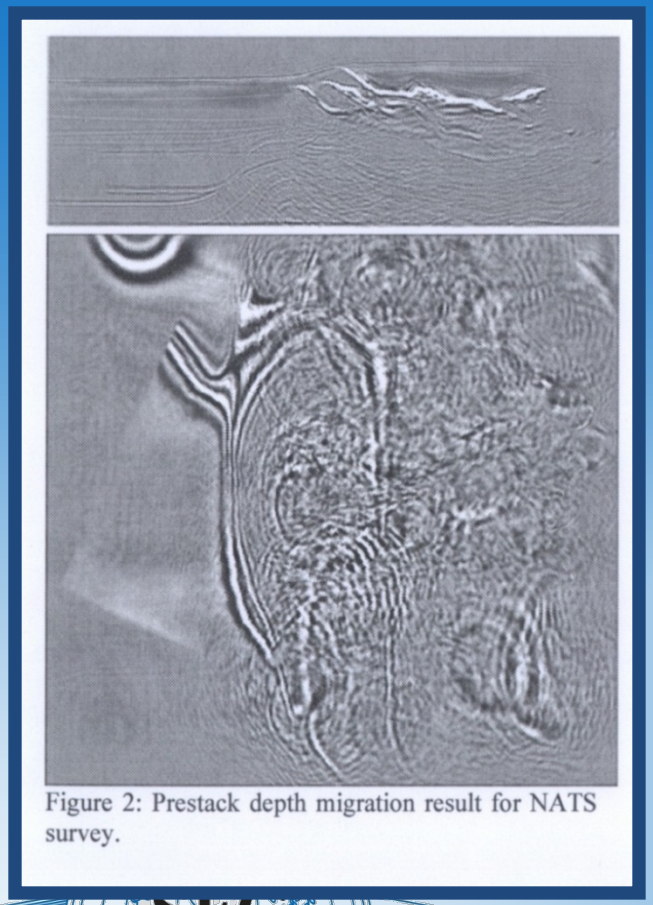


Figure 2: Prestack depth migration result for NATS survey.

NATS

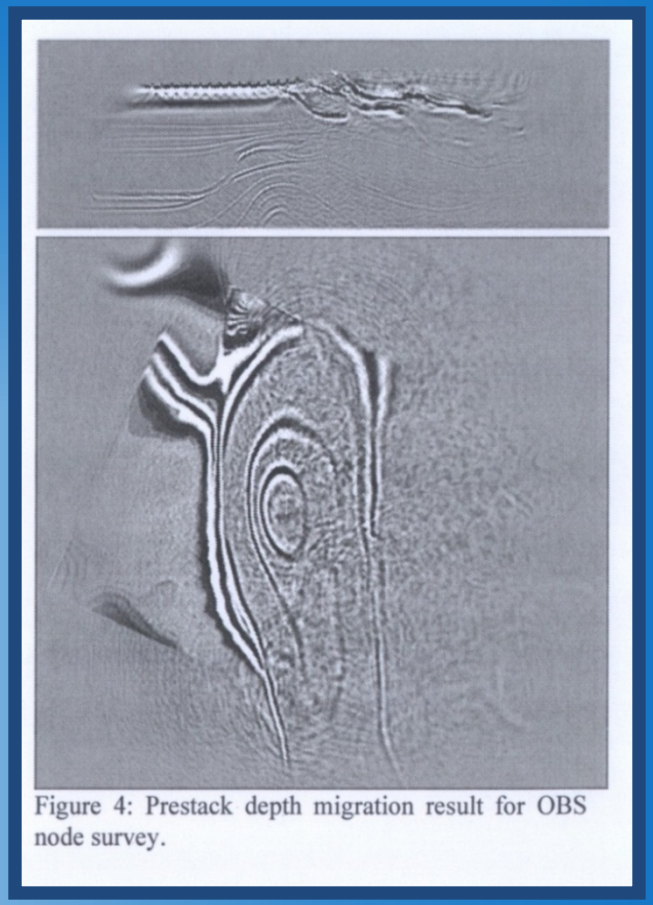


Figure 4: Prestack depth migration result for OBS node survey.

NODES

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Regone, C., 2006, A modeling approach to wide-azimuth design for subsalt imaging: The Leading Edge, 25, 1467-1475.

NATS Z3000 Wide Azimuth OBN

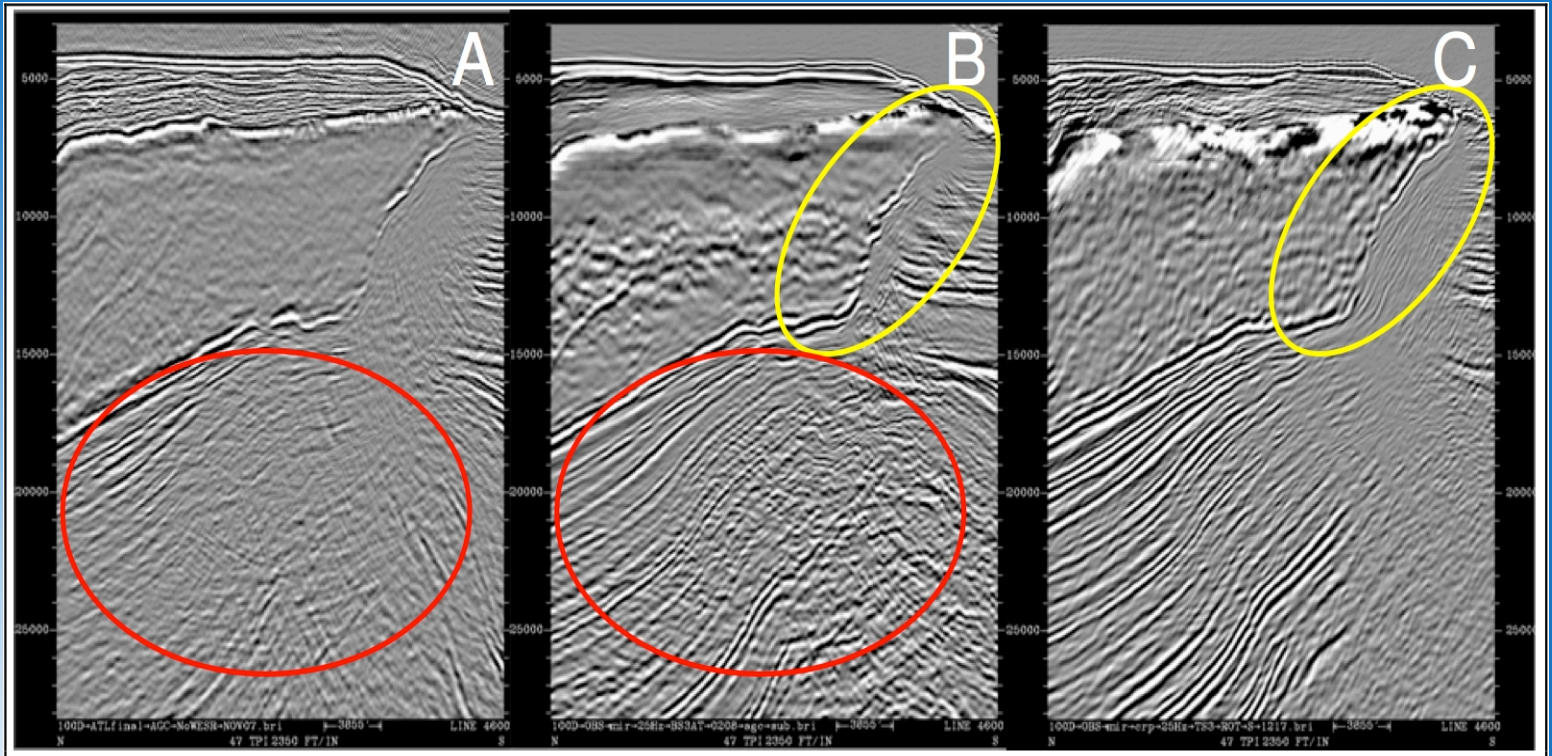


Figure 3: Comparison of narrow-azimuth towed streamer (A), shot-migrated OBS node (B) and rotated shot migration of node data (C). The node images benefit from an improved salt model. Subsalt reflectors (red ellipses) are clearly improved in the node image (B) over the streamer data (A). The steeply-dipping leading edge (yellow ellipses) of the Atlantis salt body is better imaged with the rotated shot migration (C). This allowed the interpretation team to more accurately define the steep flanks of the salt mass during the salt rebuild project. Note too that the north-dipping sub-salt sediment reflections have higher signal-to-noise in the rotated image C.

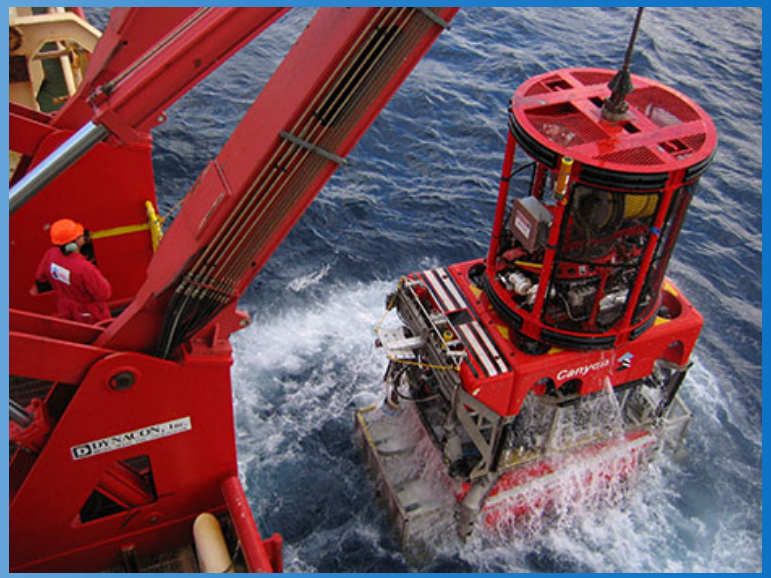
Howie, et al., 2008

Deepwater Acquisition by Z-Node
Z-节点的深海采集



The Z3000 is depth-rated for 3000 m of water depth and are typically deployed with 400 m spacing.
Z 3000用于3000米水深，一般间距为400米。
Each autonomous Z 3000 node is a self-contained sensor with a state-of-the-art lithium-ion battery and a highly accurate clock.
每个自动的Z3000节点都是一个独立的带有最先进的锂离子电池和高精度计时器的传感器。
An remote-operated-vehicle (ROV) - a long familiar apparatus in the petroleum industry - lays the units directly on the seabed where they continuously record sound waves emanating from a source vessel at the water's surface.
一个遥控操作装置（ROV）-石油工业中的一个非常熟悉的设备—将装置直接放在海底，在海底它们连续记录从海面上震源船发射出的声波。





Courtesy of Fairfield

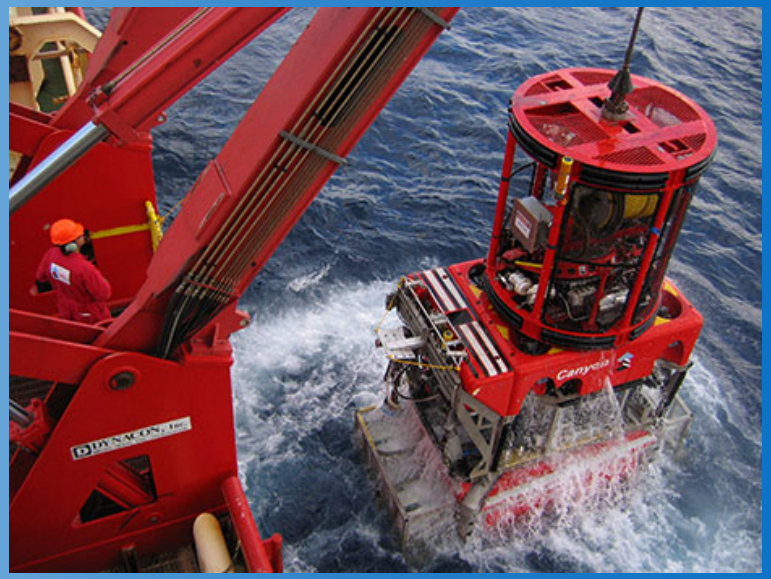
Deepwater Acquisition by Z-Node
Z-节点的深海采集





The ROV later retrieves the nodes to download the data while recharging the batteries, which are timed to last 28 days.
随后ROV收回节点用来下载数据同时给电池充电，这些数据是前28天记录的。

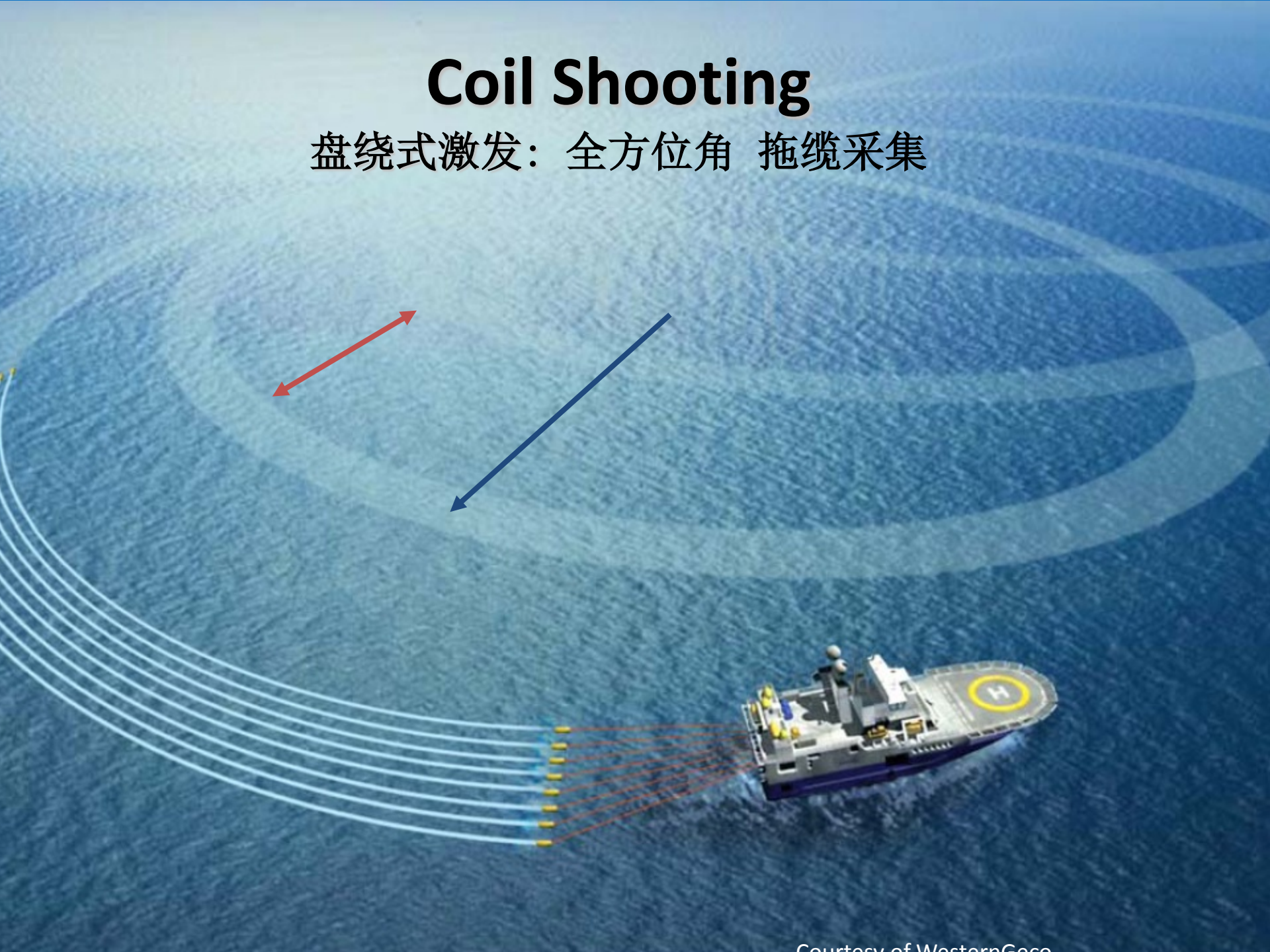
It is noteworthy that systems operations require about half the crew members of a conventional OBC shoot and only two vessels: the node management vessel and a dual source shooting vessel.
值得注意的是，常规海底电缆激发系统操作需要大约一半的工作人员和仅仅两条船：节点管理船和双源激发船



Courtesy of Fairfield

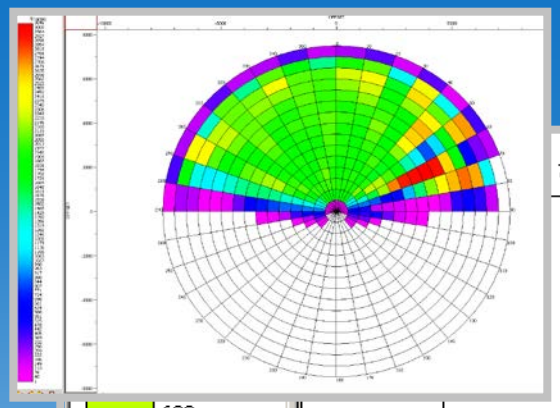
Coil Shooting

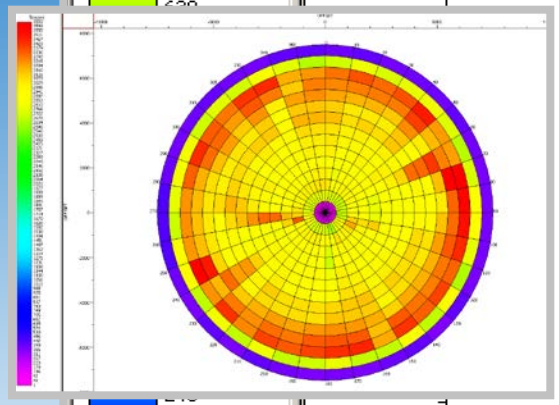
盘绕式激发：全方位角 拖缆采集

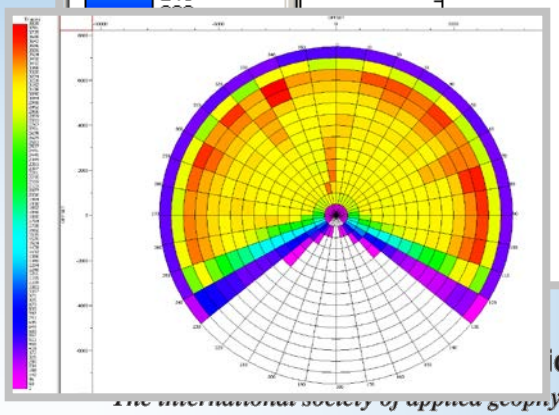


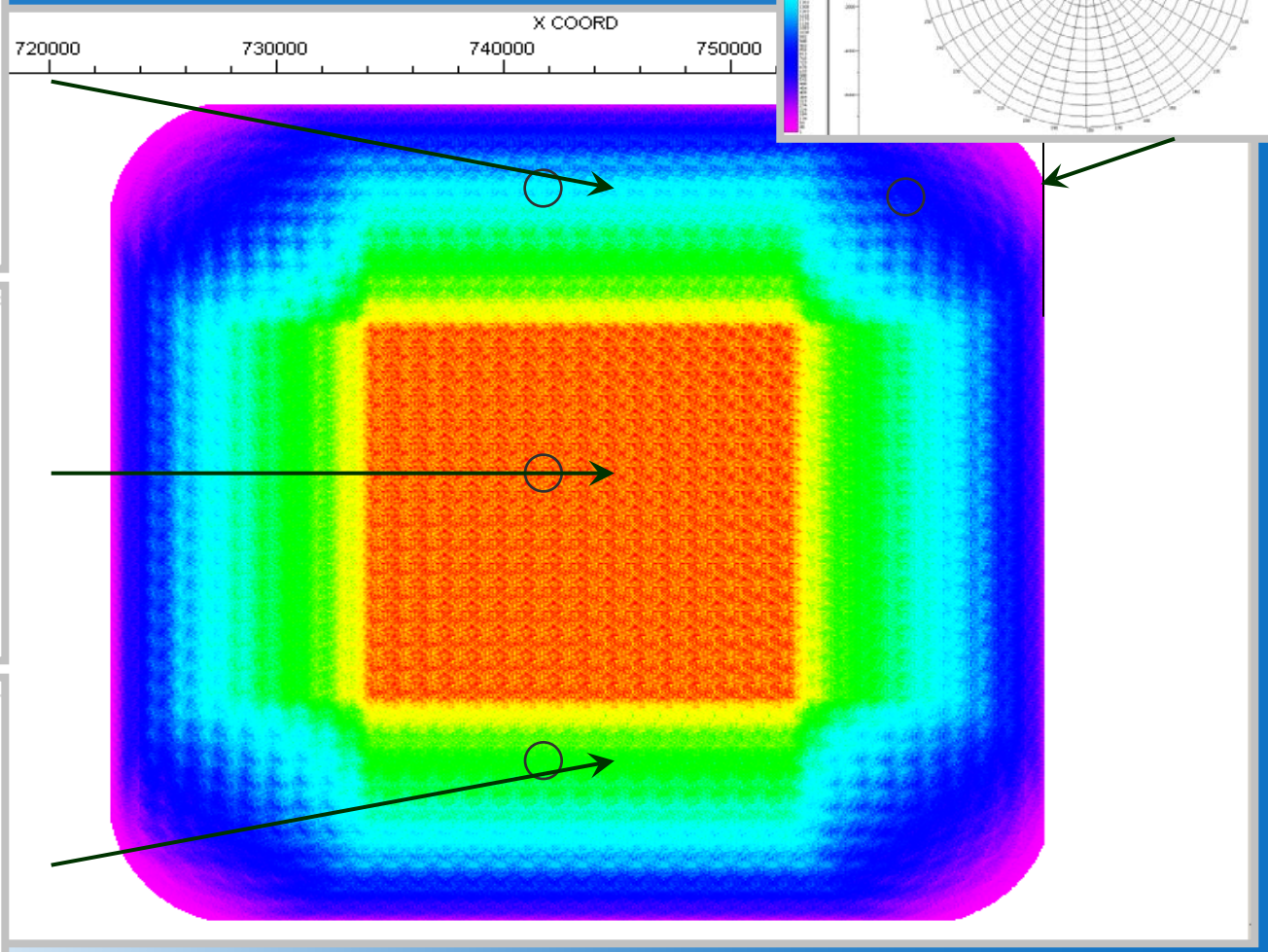
Courtesy of WesternGeco

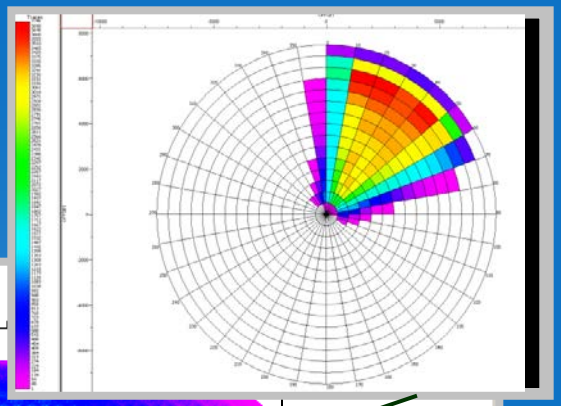
Single Coil Acquisition
单环拖缆采集





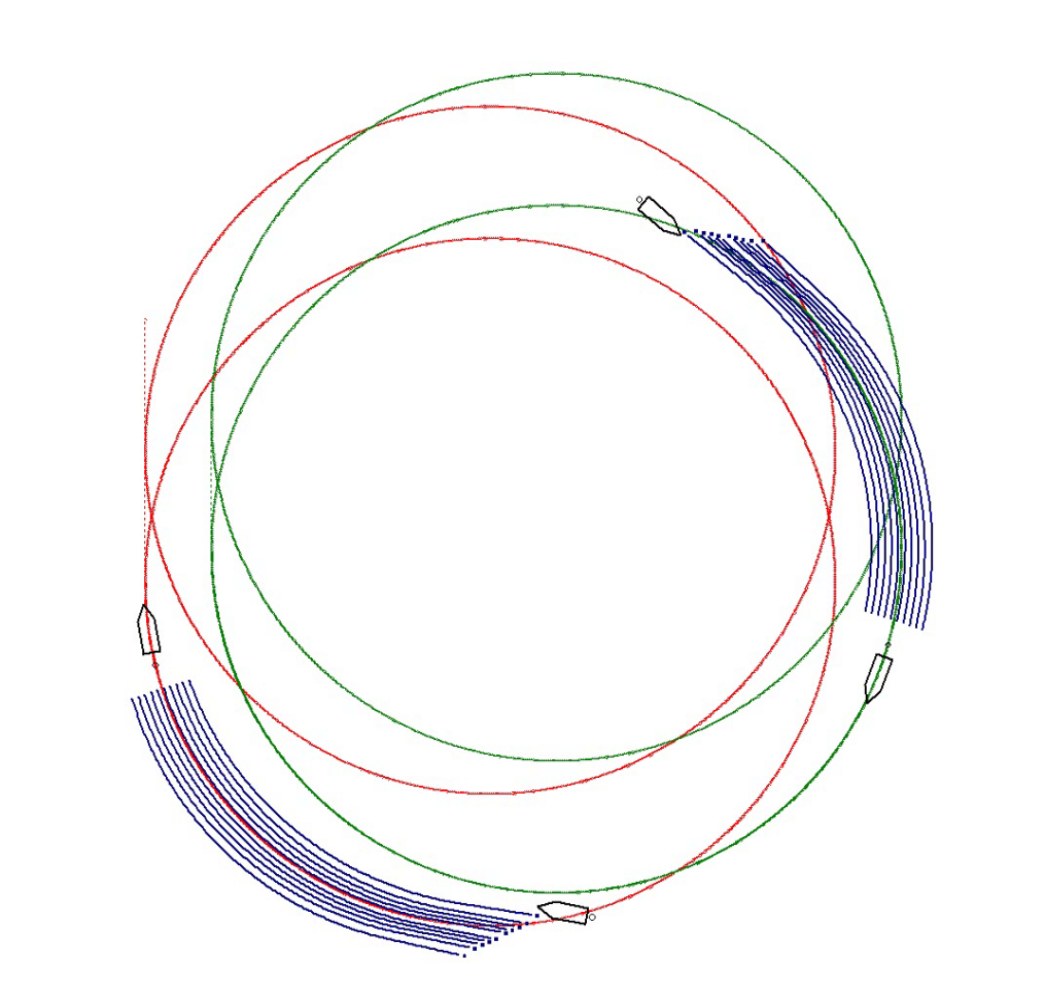






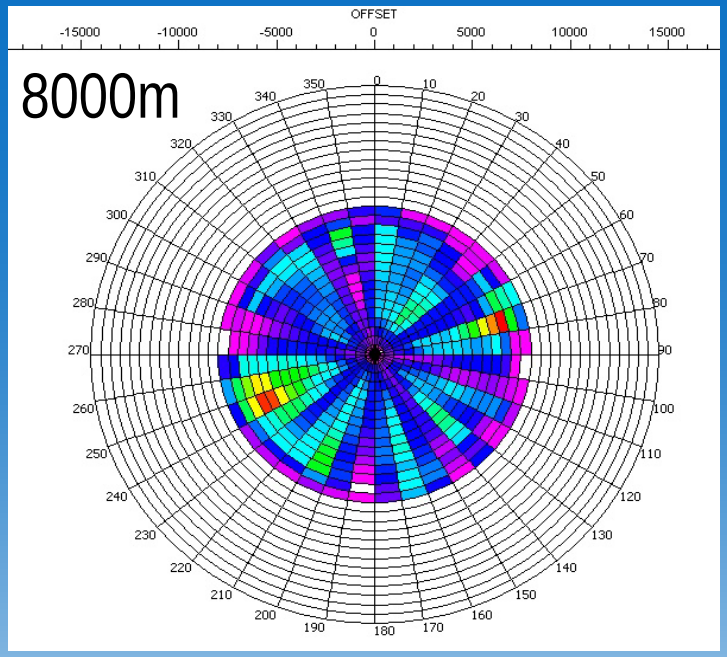
Courtesy of WesternGeco

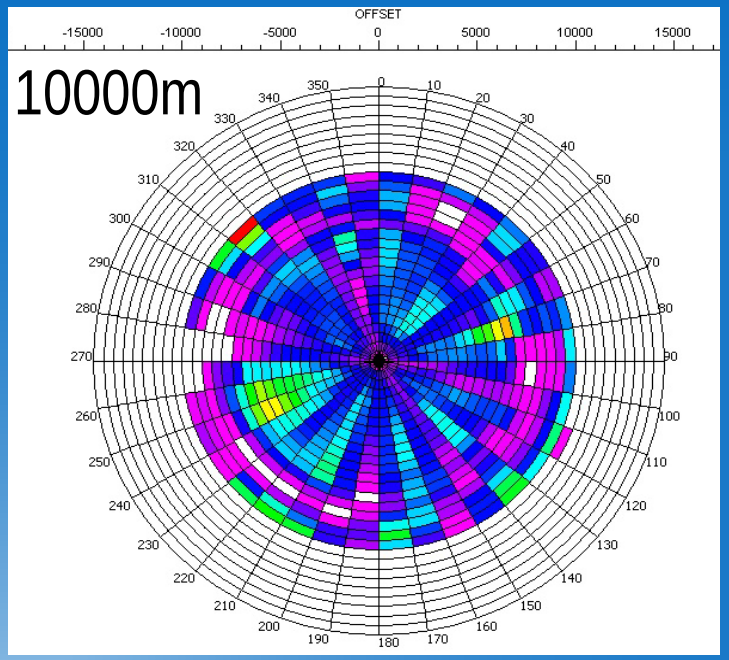
2 x 4 Coil Shooting Acquisition
2 x 4 盘绕式激发拖缆采集

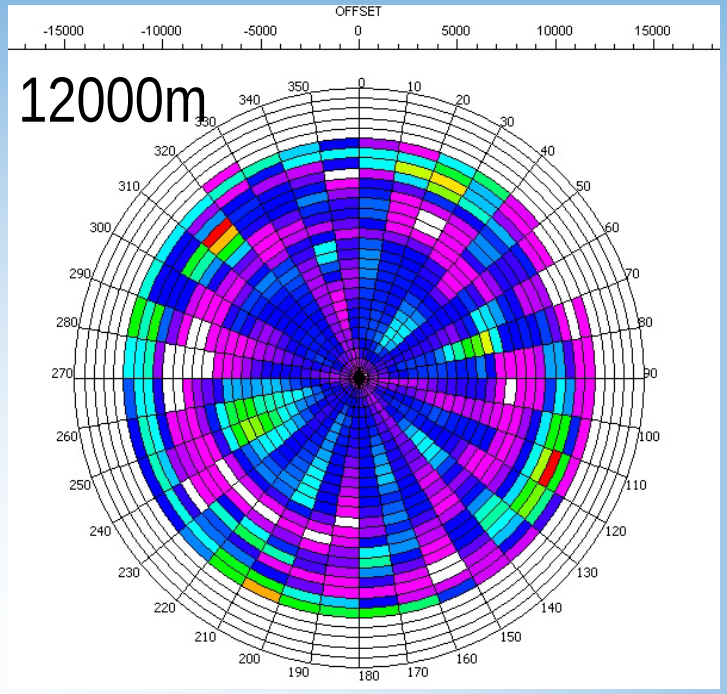


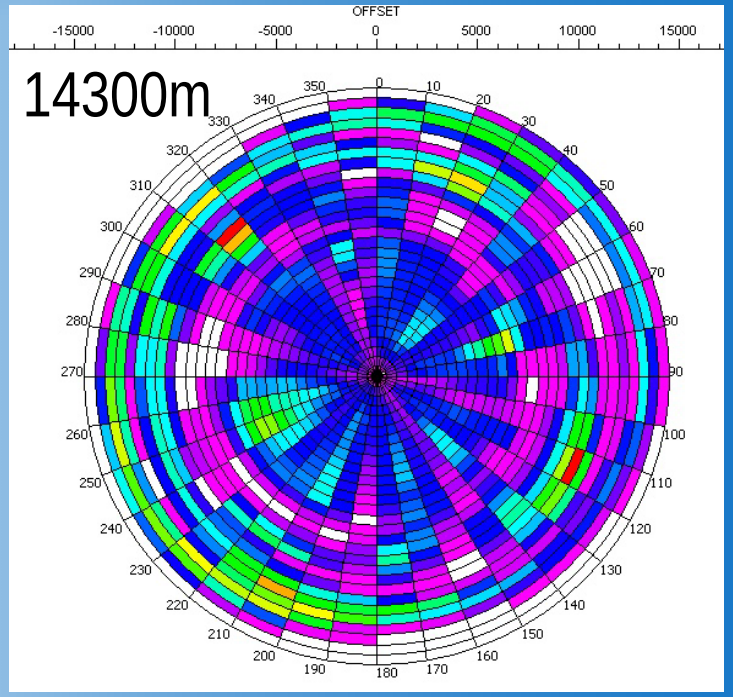
Courtesy of WesternGeco

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8000m
OFFSET
-15000 -10000 -5000 0 5000 10000 15000


10000m
OFFSET
-15000 -10000 -5000 0 5000 10000 15000


12000m
OFFSET
-15000 -10000 -5000 0 5000 10000 15000


14300m
OFFSET
-15000 -10000 -5000 0 5000 10000 15000

Have we solved the sub-salt imaging problems?

我们已经解决盐丘下方成像问题了吗？

- With WAZ/WATS, OBN, coil surveys
  运用WAZ/WATS, OBN, COIL 勘探
- 3D SRME
  三维去除地表相关多次波
- Grid–base tomographic inversion
  基于网格的层析成像反演
- RTM w/GPU's
  逆时偏移/GPU加速
- Dirty salt model 泥质盐丘模型
- FWI 全波形反演
- ……

Any Questions?



Courtesy of WesternGeco

Presentation Outline
报告提纲

- Recent advances in sub-salt imaging
  盐丘下方成像最新进展
- **Broadband seismology　宽带地震学**
- 3D seismology for unconventional resources development
- 非常规能源开发的三维地震
- Summaries　总结

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GEOPHYSICS, VOL.78 NO.2
(MARCH-APRIL 2013)

Why?

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Special Section

Broadband seismology in oil and gas exploration and production — Introduction

Johan O. A. Robertsson[1], Shuki Ronen[2], Satish Singh[3], and Roald van Borselen[4]

The last decade has seen considerable success toward solving long-standing exploration and reservoir characterization challenges, such as subsalt reservoir imaging. These advances have been enabled through new acquisition techniques in combination with advances in methods for processing, imaging and inversion of seismic data that is rich in low frequencies. In particular, methods such as reverse-time migration rely on highly accurate velocity models. Deriving such velocity models in turn fundamentally requires the acquisition of low-frequency seismic data. In addition, as is nicely demonstrated in one of the papers in this special section, low frequency

based on advances in acquisition technology such as multicomponent streamers, ambient noise recordings or vibroseis sweep technology. In particular, methods relying on multicomponent streamers achieve separation of up- and downgoing wavefields through the combination of complementary measurements sometimes is referred to as wavefield decomposition as opposed to deghosting (the latter relying on pressure data only). Third, papers have been included that suggest new ways of acquiring and processing data that naturally ensure data with temporal and spatial bandwidth fit for imaging and inversion.

Why Broadband (Low Frequency) ??

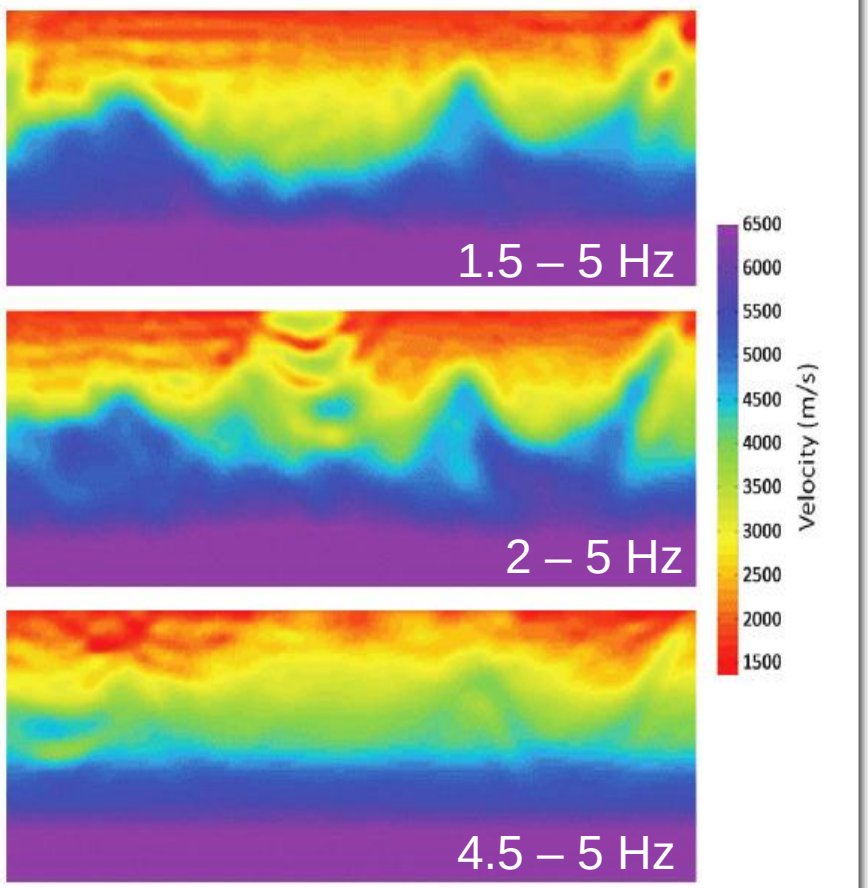


Figure 19. Velocity models obtained from full-waveform inversion in the $v_0 + kz$ starting model and using frequency bands 1.5–5 (top), 2–5 (middle), and 4.5–5 Hz (bottom).

- Less side lobes, sharper images
- Low frequencies for FWI
- Low frequencies for impedance inversions
- Deeper penetration

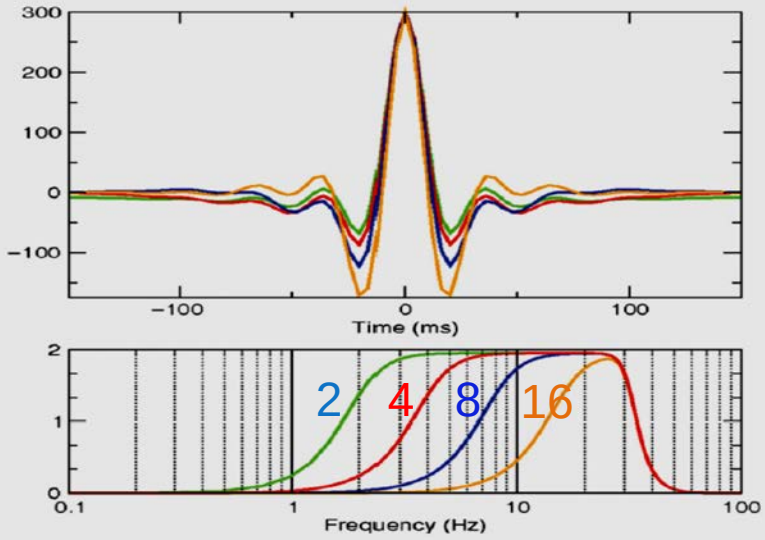


Figure 1. Butterworth filter high cut 32 Hz and 12 dB/octave low cut at 2 (green), 4 (red), 8 (blue), and 16 Hz (yellow).

Ten Kroode et al. 2013

Broadband Seismology
宽带地震学

- **Wavefield Separation** 波场分离
  - **Solid cable w/geophone & hydrophone sensors (dual sensors)**
    实心电缆/检波器 和 水听传感器(双传感器)
  - **Variable-depth streamer (VDS)**
    变深度电缆
  - **Coded delayed, time and depth, sources**
    编码的震源
- **Mirror migration process** 镜像偏移处理
- **De-ghosting Process** 去除鬼波处理



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Solid cable w/geophone & hydrophone sensors (dual sensors)
固态电缆/地震检波器 & 水听器（双传感器）

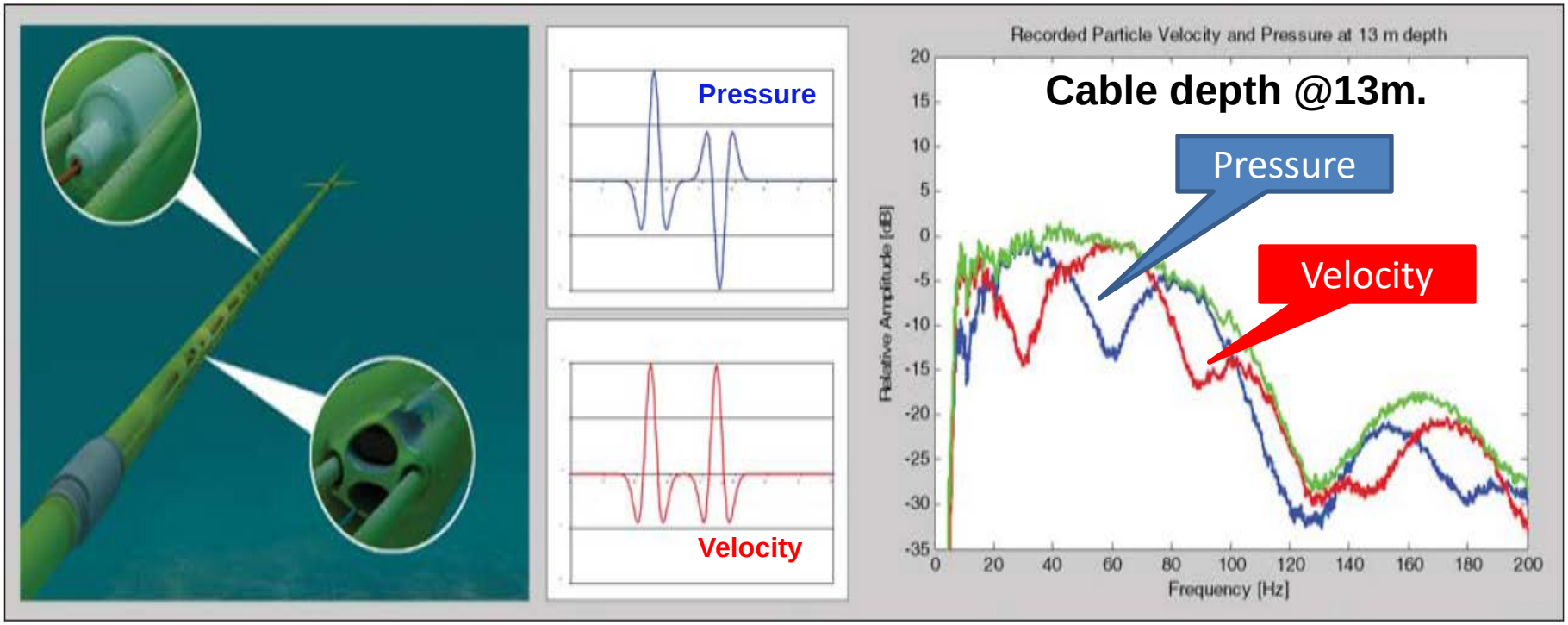
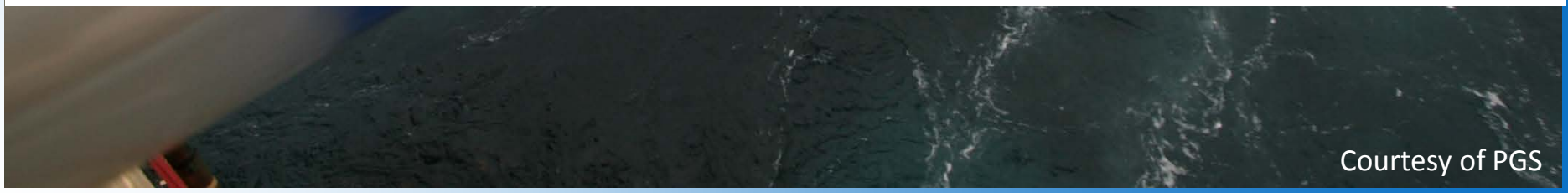
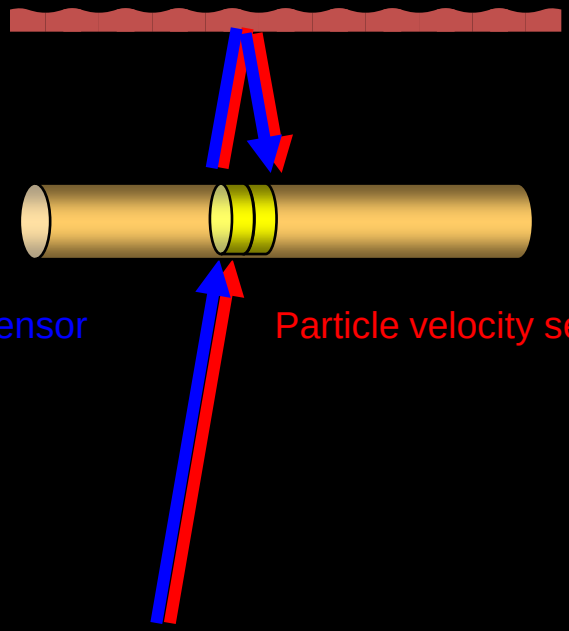


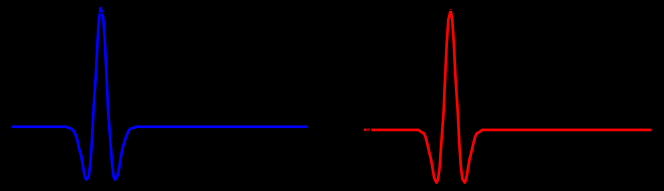
Figure 5: Receiver ghost reflection cancellation using a dual-sensor streamer. The green curve in the amplitude spectrum is the up-going pressure data after the removal of the receiver ghost effects. Blue is the pressure sensor data and red is the velocity sensor data.

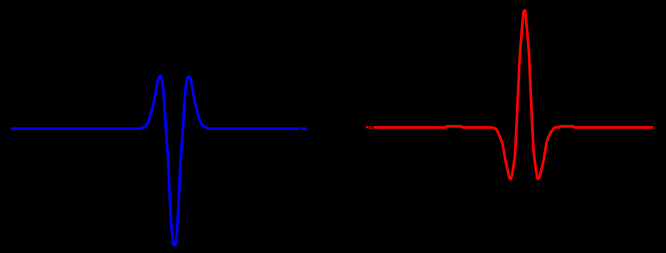


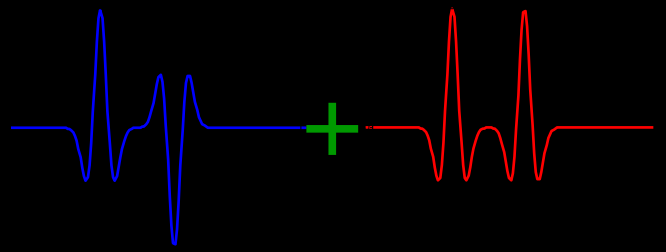
Courtesy of PGS

Up- and Down- Going Waves
上行波/下行波







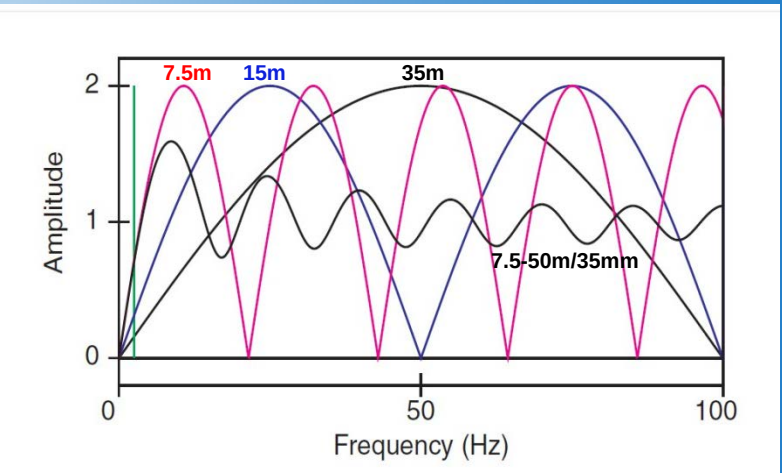


Downgoing wave (ghost): 下行波(鬼波)
The sea surface acts like a perfect mirror and sends back the wave with a reverse polarity.
海面像是一个完美的镜面，反射回来具有极性相反的波

For the velocity sensor the push then becomes a pull.
对于速度传感器推力变为牵引力
Remember: a pull from above = a push from below => recorded as a positive by the velocity sensor.
记住：上部的牵引力=下部的推力=>速度传感器记录为正值

Principle of Variable-Depth Acquisition/Imaging
变深度电缆采集/成像的原则

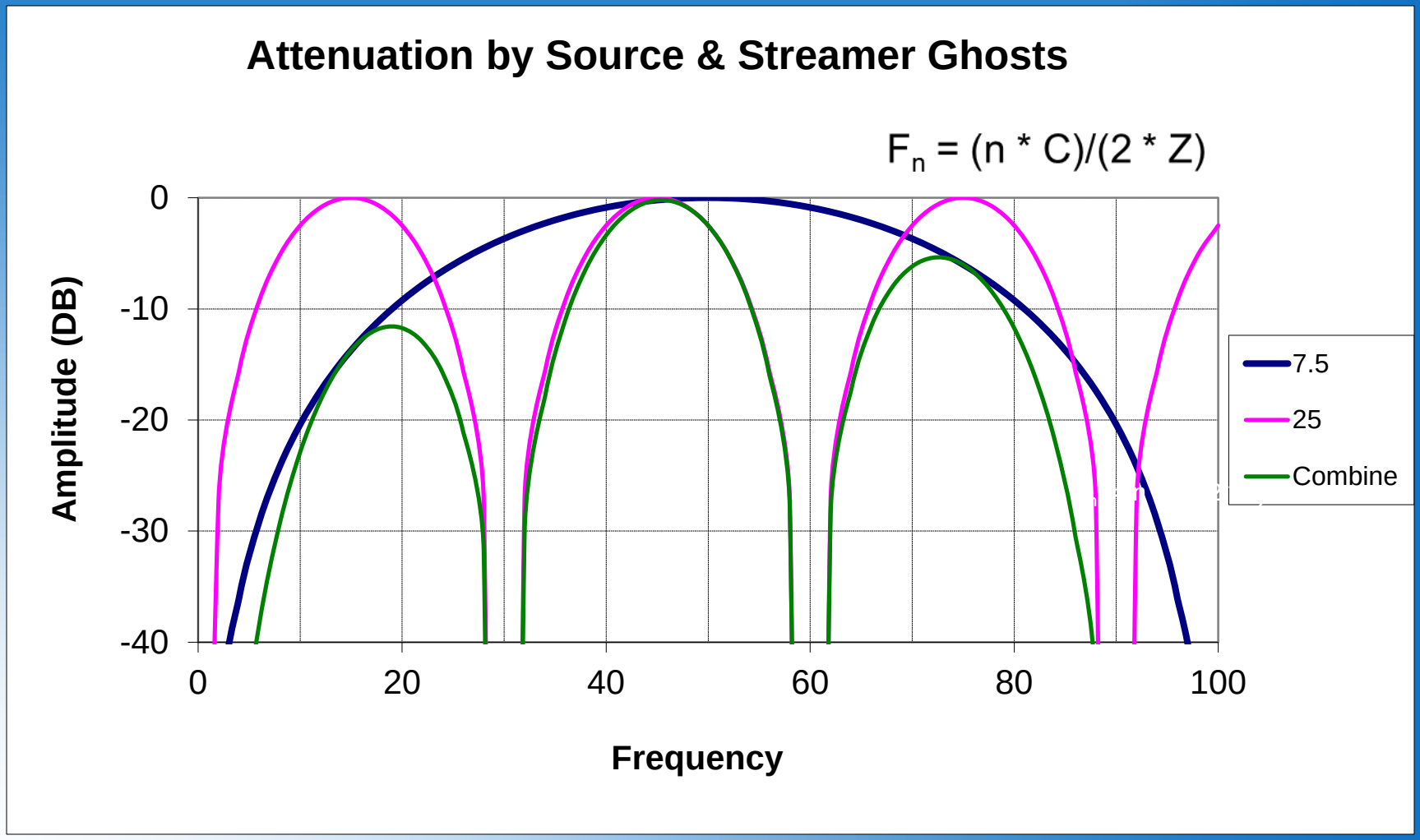
- **Variable depth towing 变深度拖拽电缆**
- **Imaging technique using “ghost notch diversity” 应用“鬼波陷波多样性”成像技术**
- **Conventional migration plus mirror migration, followed by Deconvolution 传统偏移方法加镜象法偏移与反褶积**



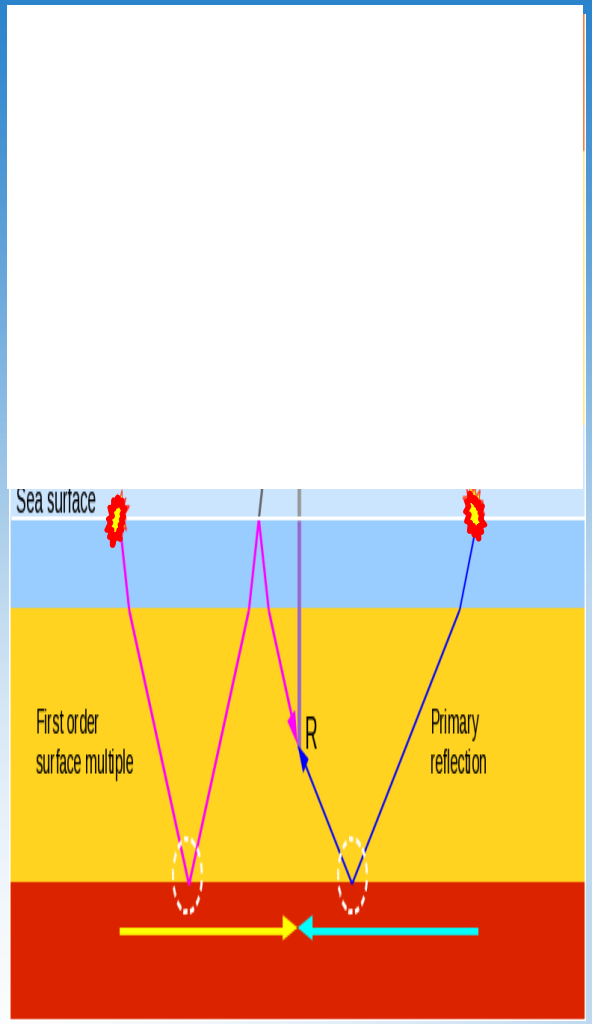
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Soubara & Lafet 2013

De-ghosting Process
去鬼波处理

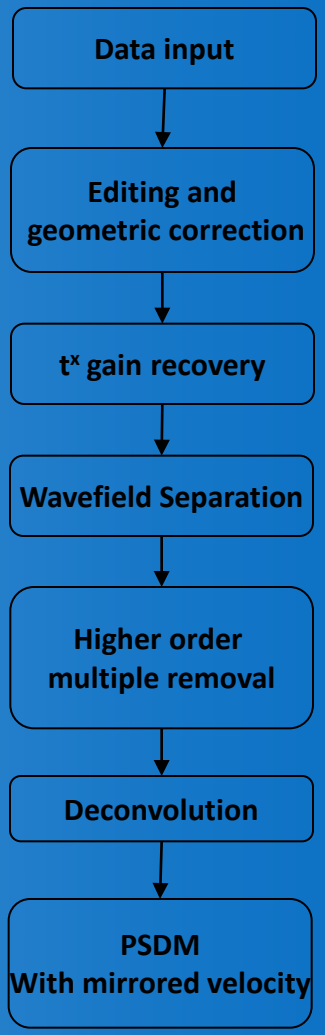


Mirror Migration

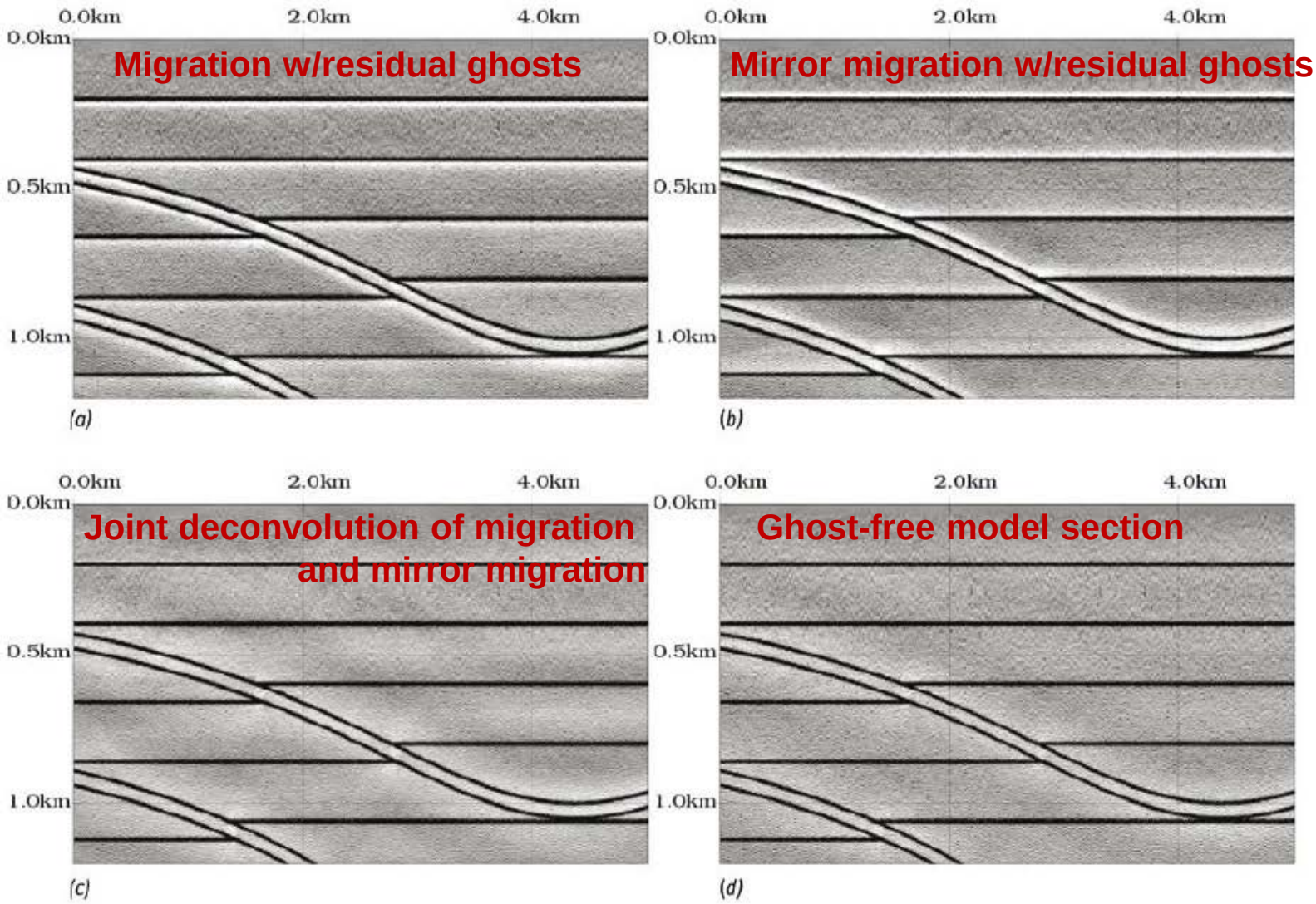


>

- Extend velocity field as mirror image above sea surface
- Replace receiver R by virtual mirror receiver at R'
- Free-surface multiple recorded at R
- Primary reflection recorded at R'
- Applies for first order multiple
- Can be generalized for higher order multiples.

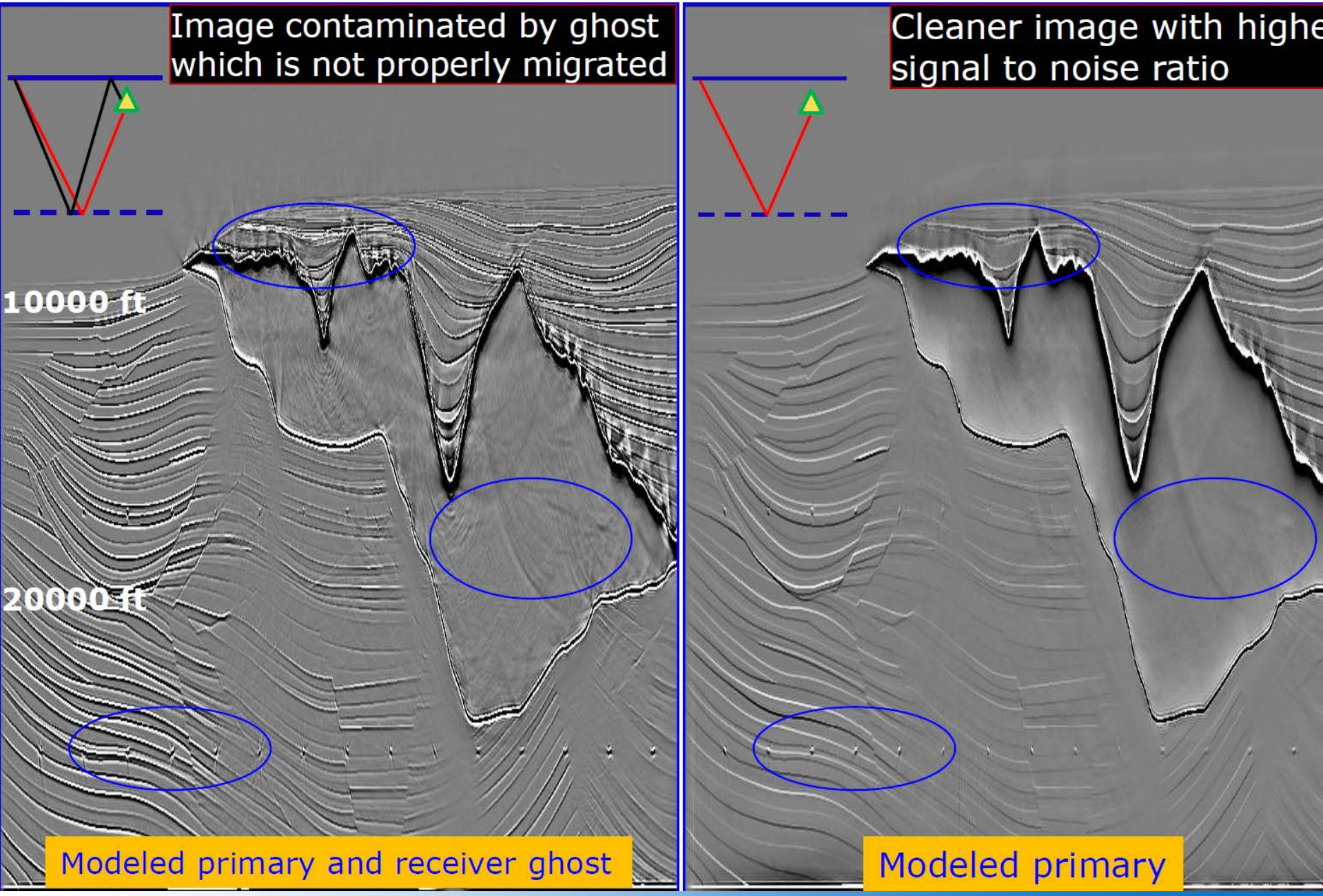


Mirror Imaging

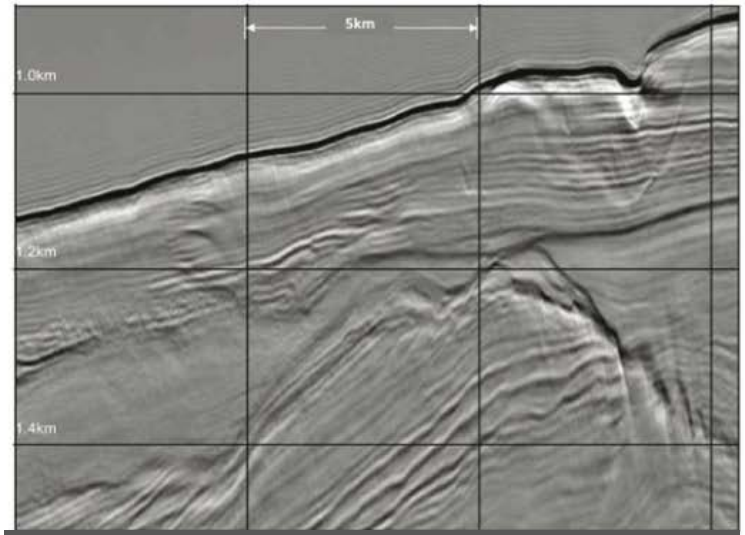


Soubara 2010

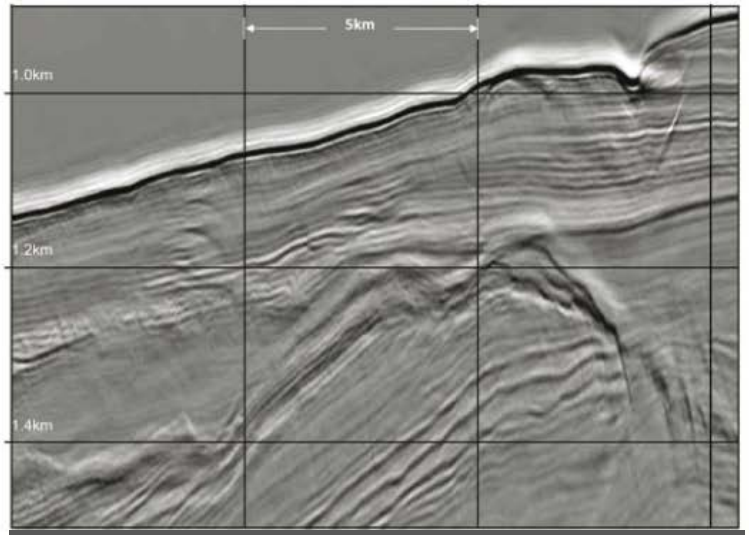
RTM: Input with and without receiver ghost



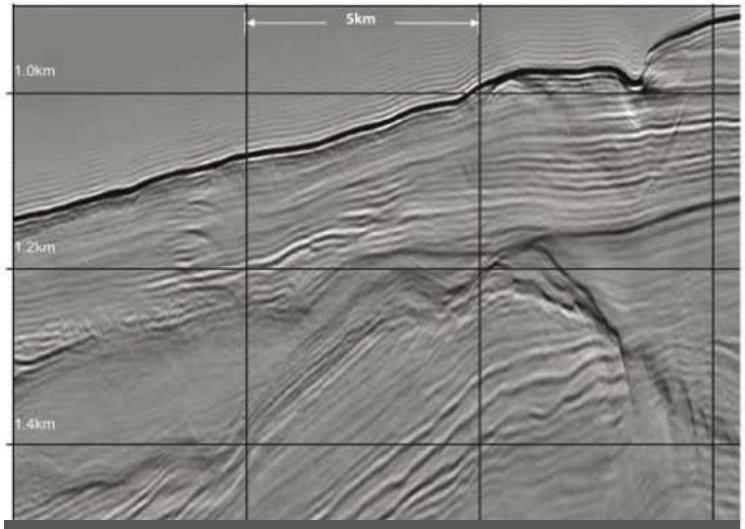
NW Australia Example



Normal Migration



Mirror Migration



Joint Deconvolution/Deghosting

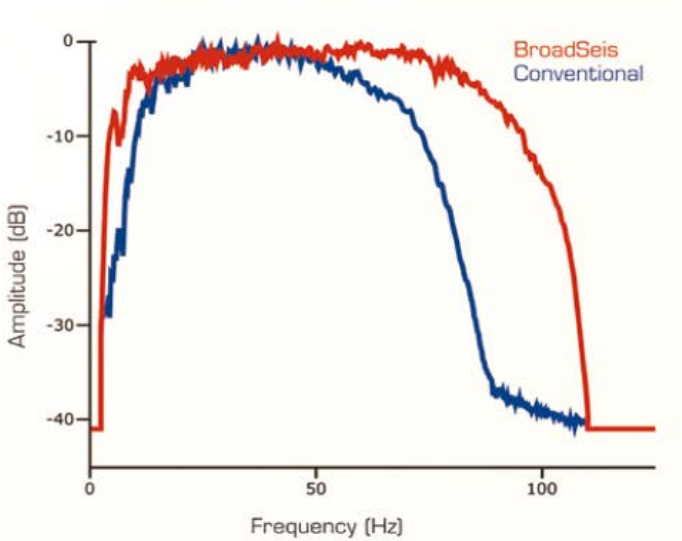
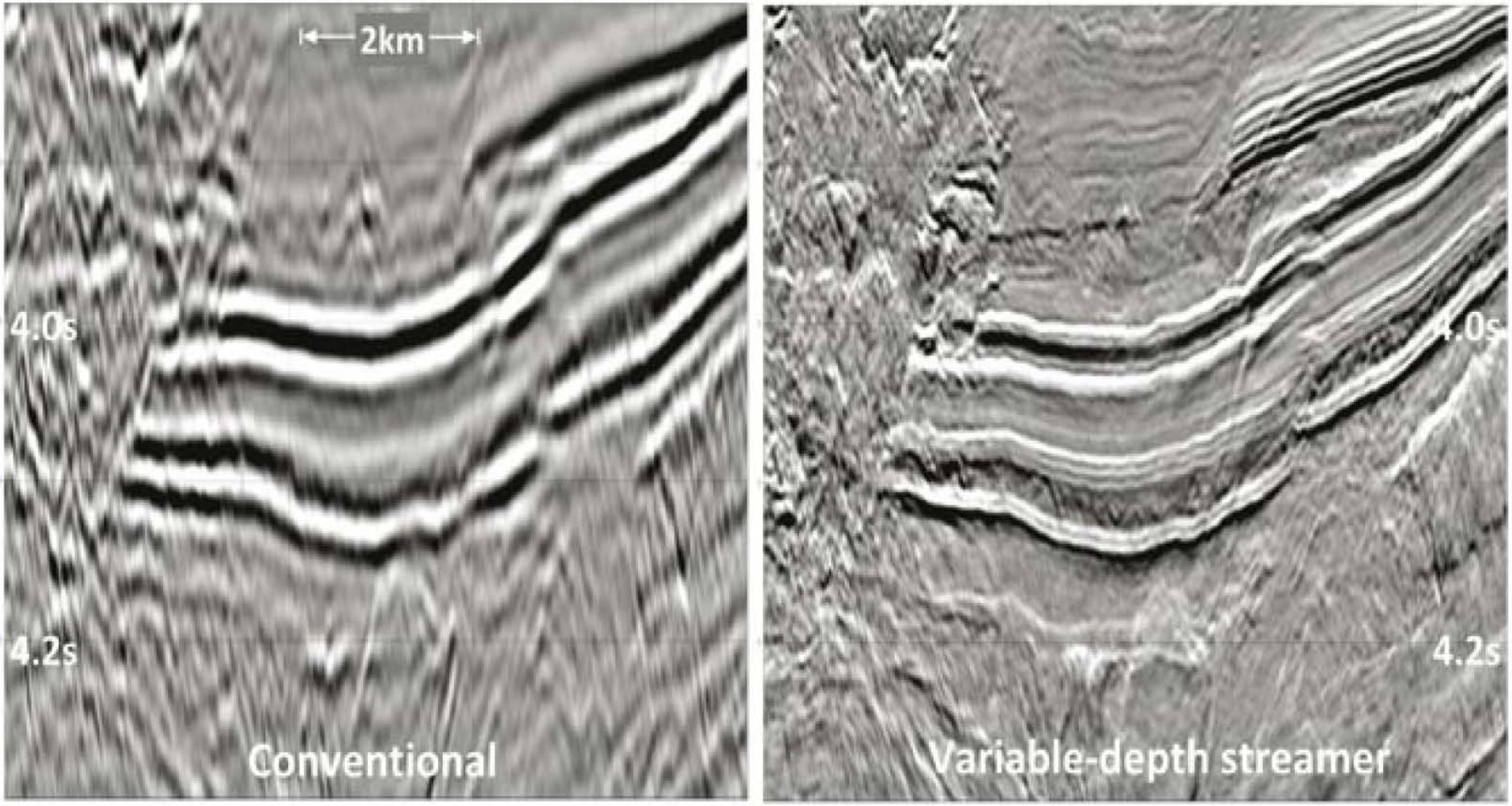
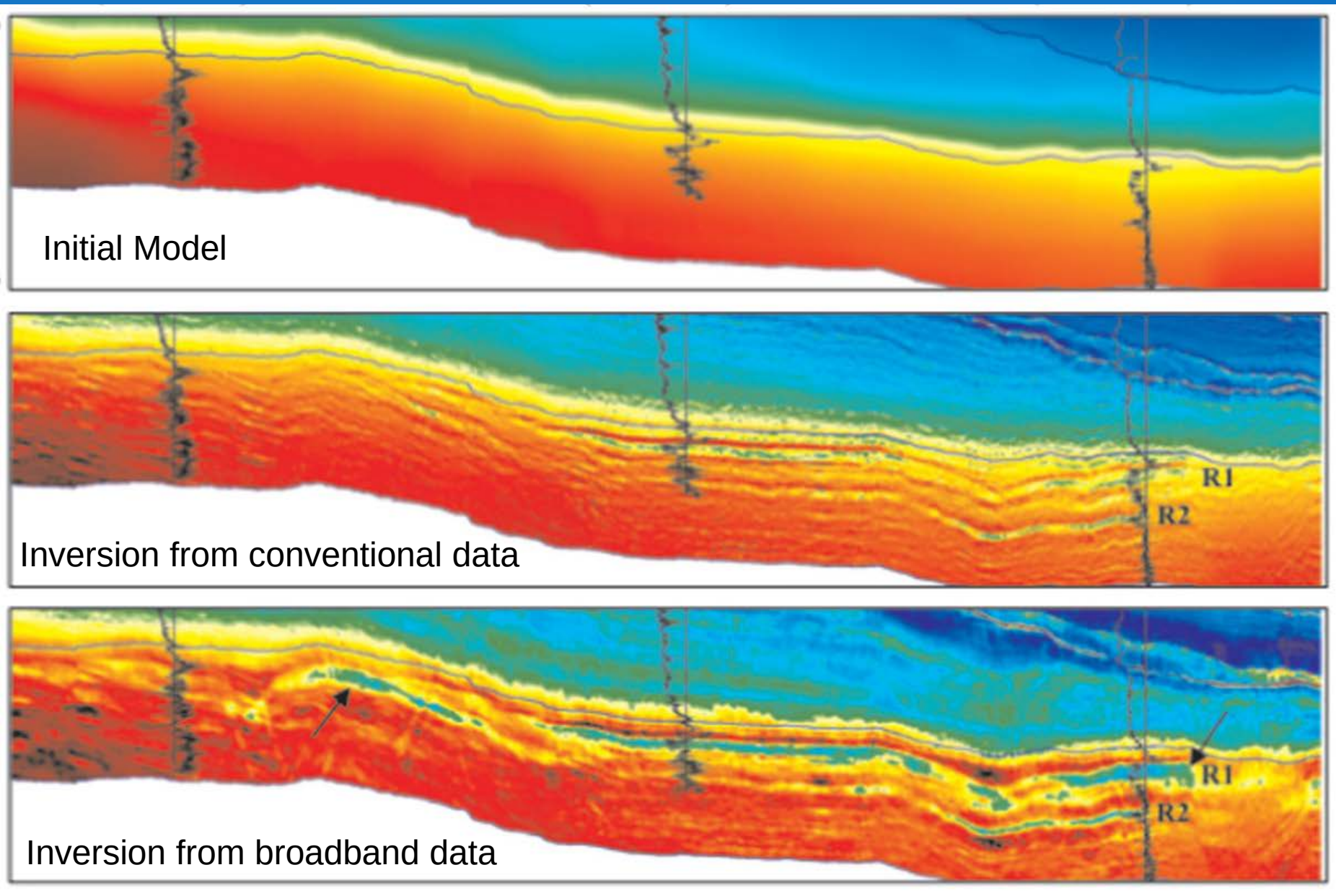


Figure 10 *NW Australia, comparison of amplitude spectra of the legacy dataset with the new broadband data. Data courtesy of CGGVeritas Data Library.*

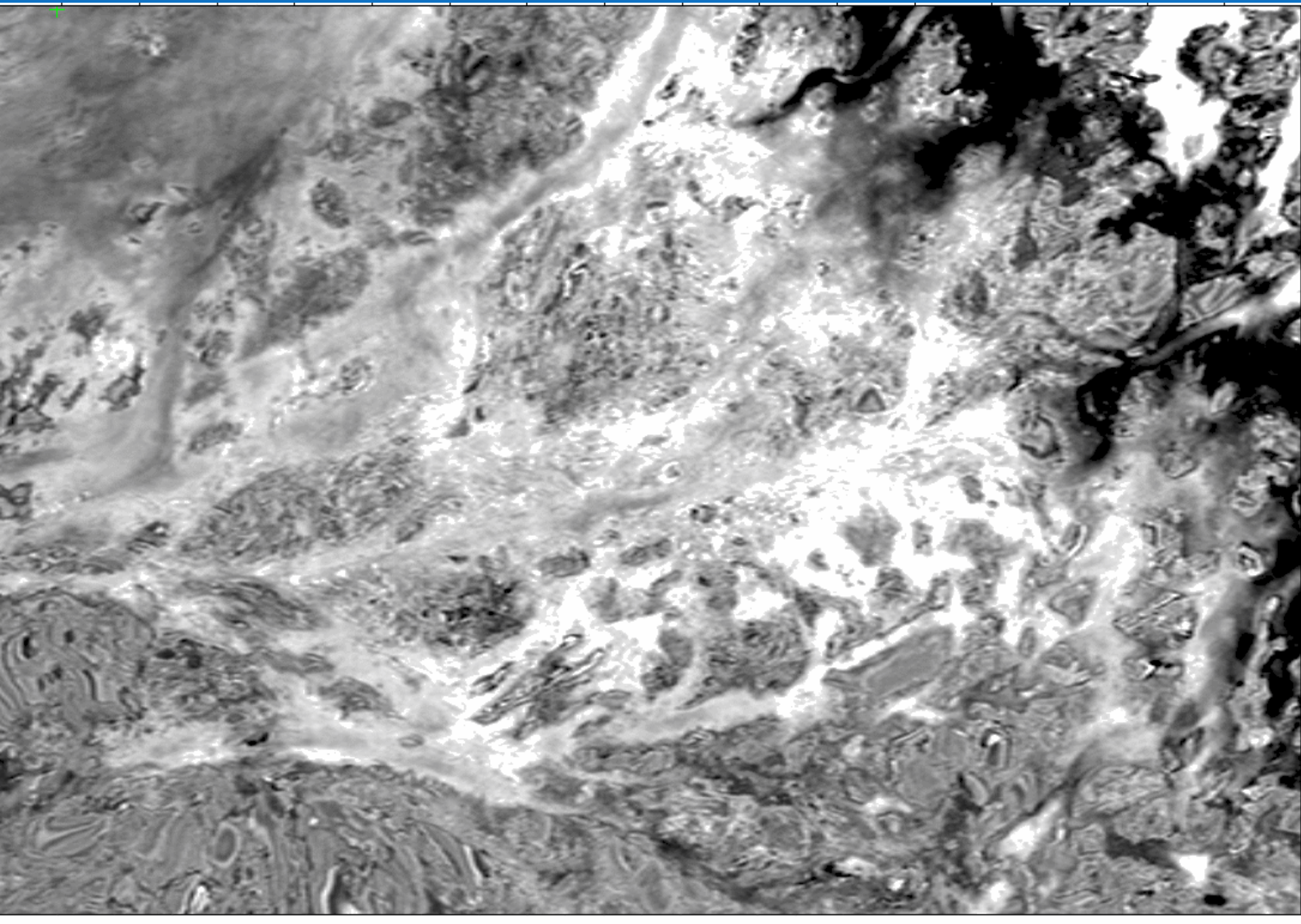
Gulf of Mexico



Acoustic Impedance Sections



Soubaras & Lafet 2013



Seismic Vibrators

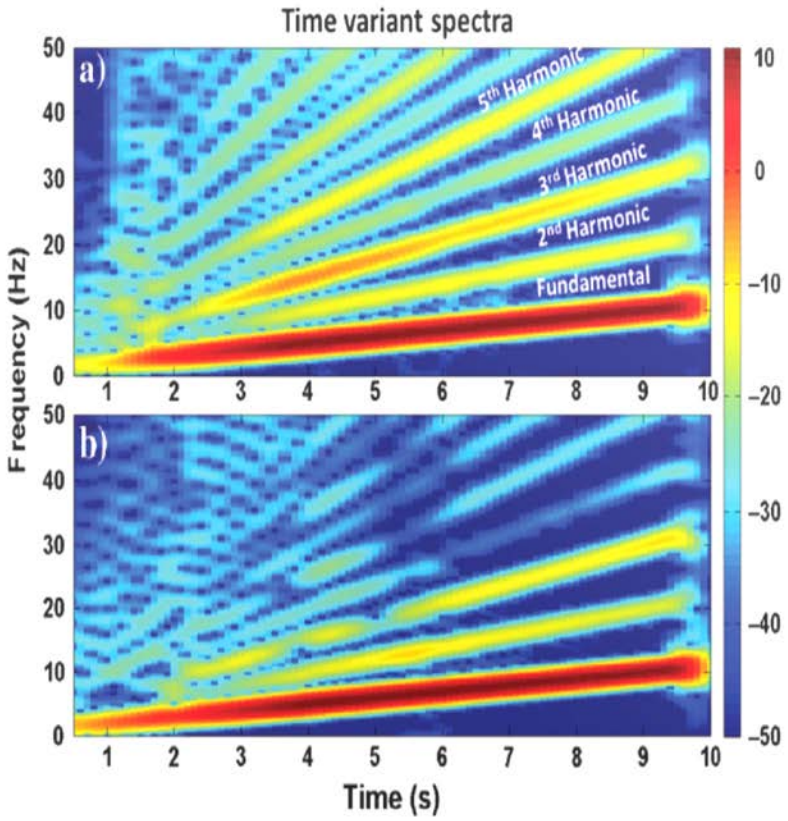


Figure 5. Time variant spectrum comparisons of the weighted-sum ground force at frequencies of 1.5–11.5 Hz. (a) the standard control; (b) the harmonic distortion reduction control.

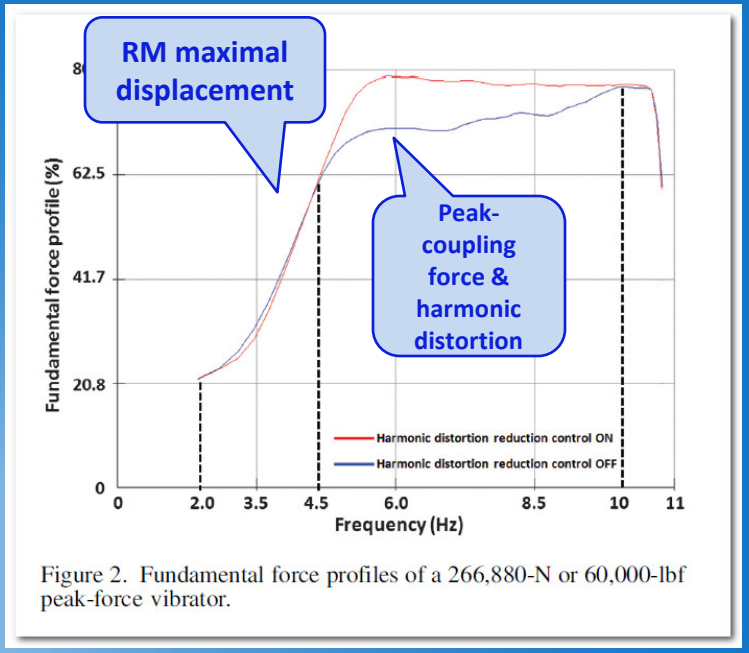


Figure 2. Fundamental force profiles of a 266,880-N or 60,000-lbf peak-force vibrator.

Low Frequency Vibratory Signals (<3 Hz.)

- Sweep rate
- Starting and ending frequencies
- Sweep length
- Low-frequency harmonic distortion reduction control

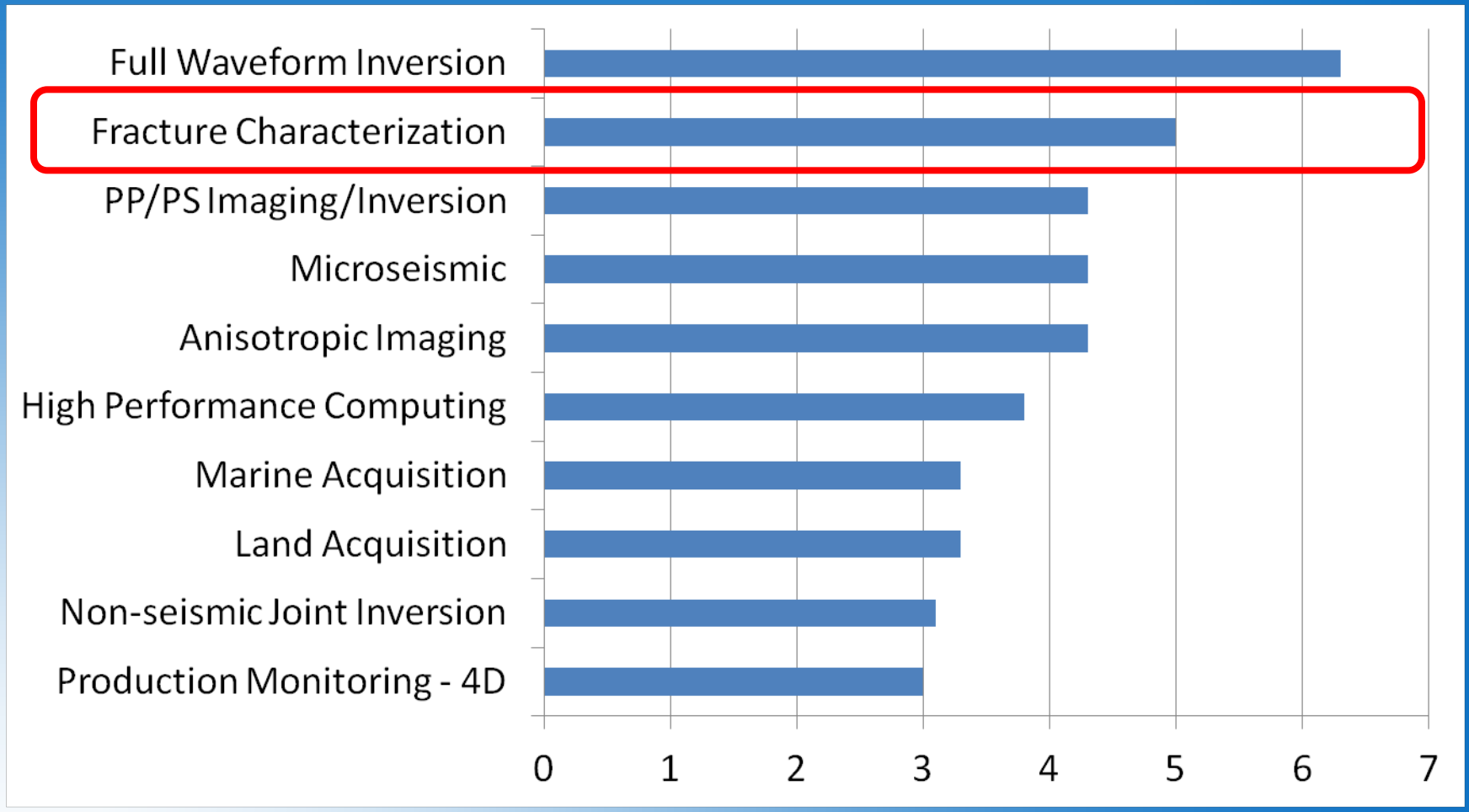
Wei & Phillips 2013

Presentation Outline
报告提纲

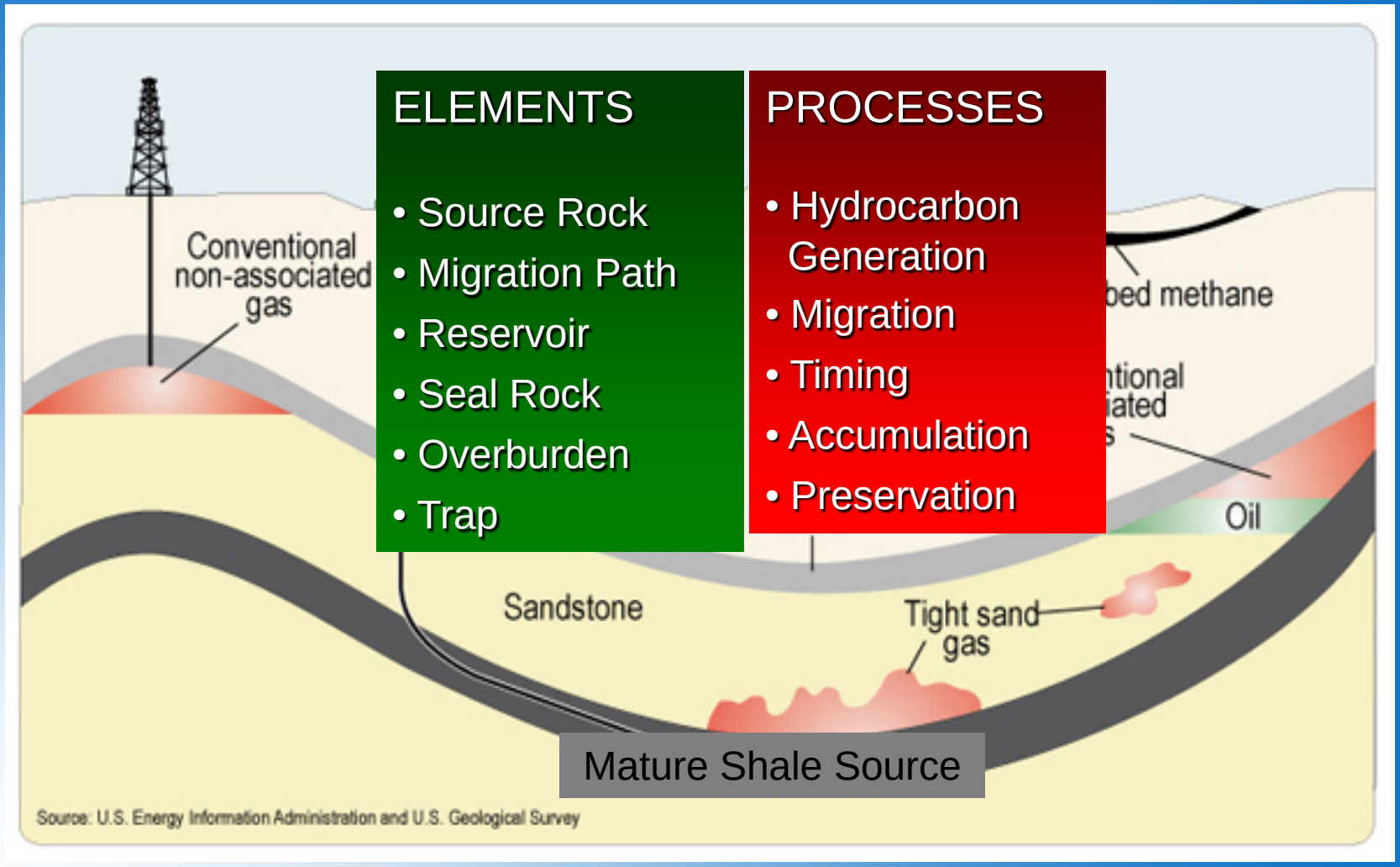
- Recent advances in sub-salt imaging
  盐丘下方成像最新进展
- Broadband seismology 宽带地震学
- **3D seismology for unconventional resources development**
  非常规能源开发的三维地震
- Summaries 总结

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SEG Research Committee Priorities
SEG研究委员会研究比例分布



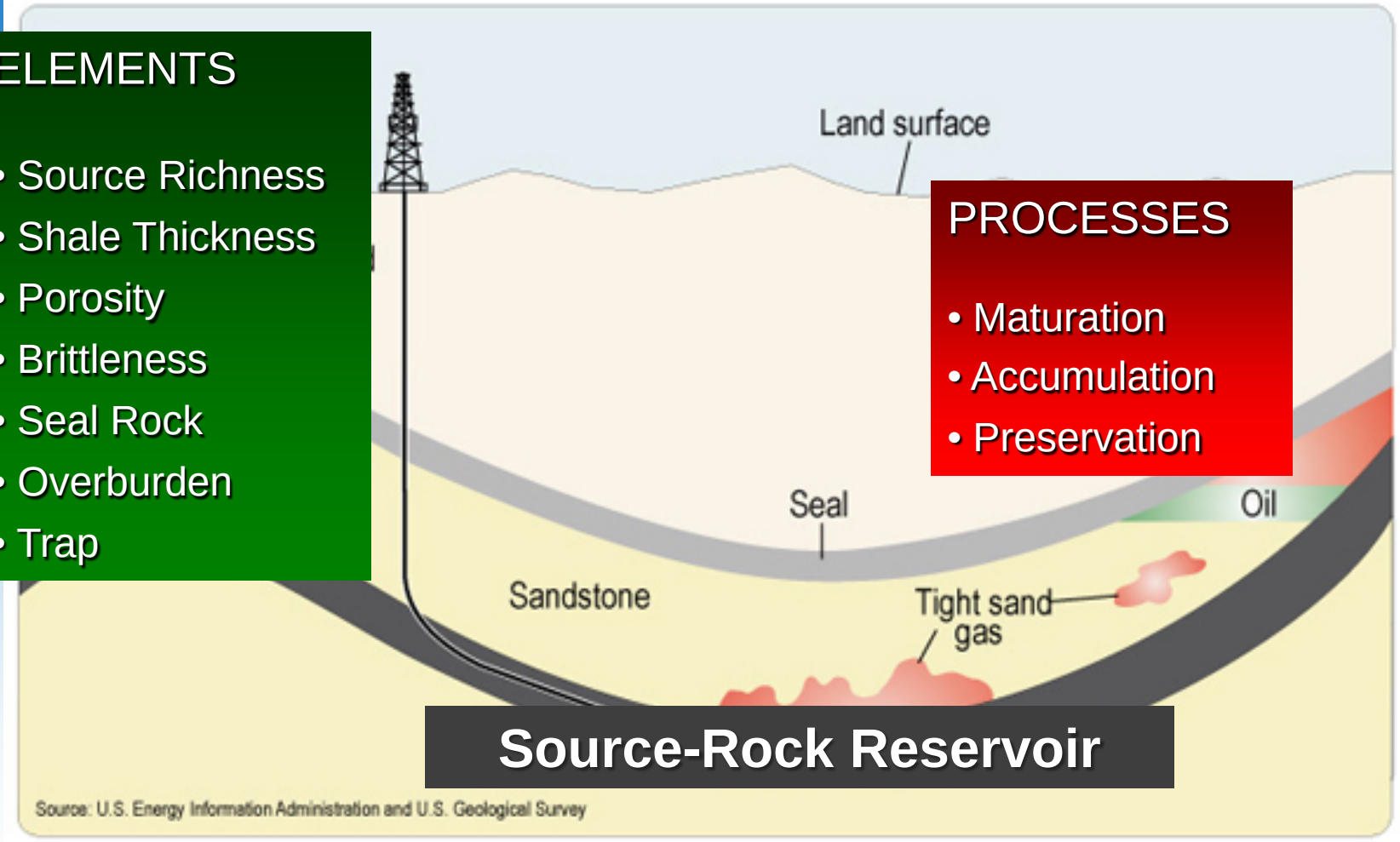
Conventional Oil & Gas Reservoirs
常规油气藏



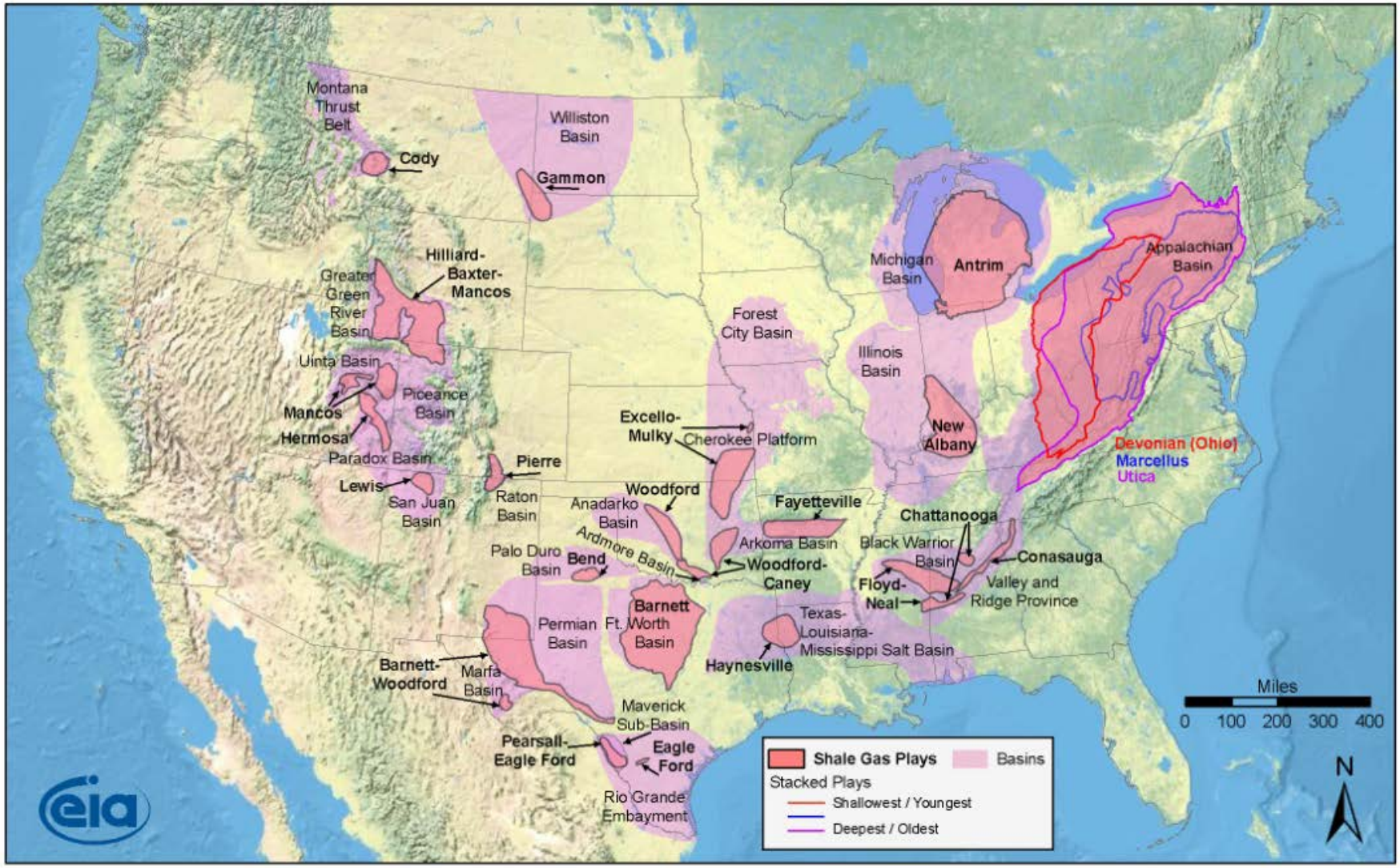
Unconventional Shale Resources Plays
非常规页岩资源

ELEMENTS

- Source Richness
- Shale Thickness
- Porosity
- Brittleness
- Seal Rock
- Overburden
- Trap

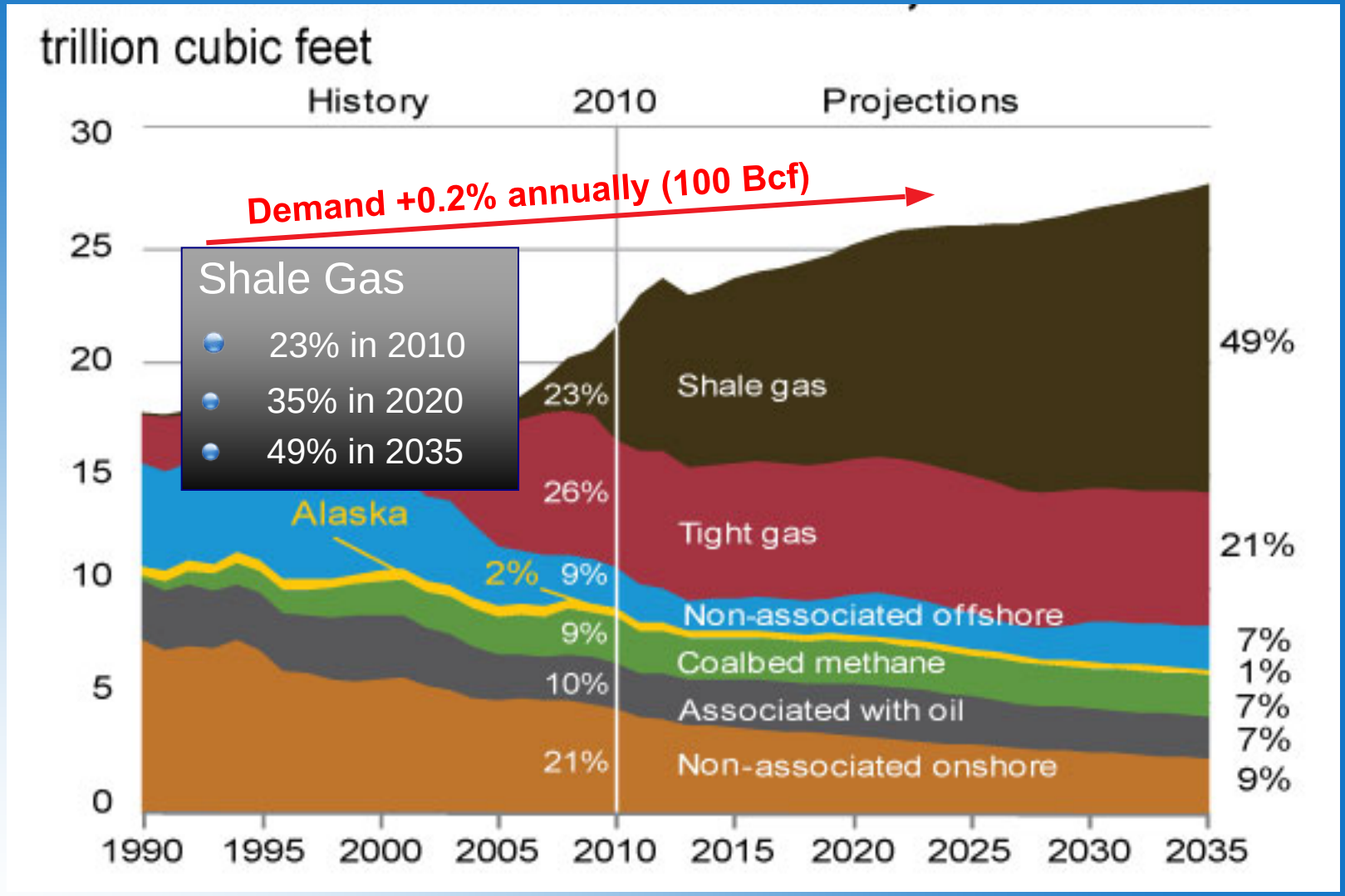


Shale Gas Plays, US Lower 48
页岩气



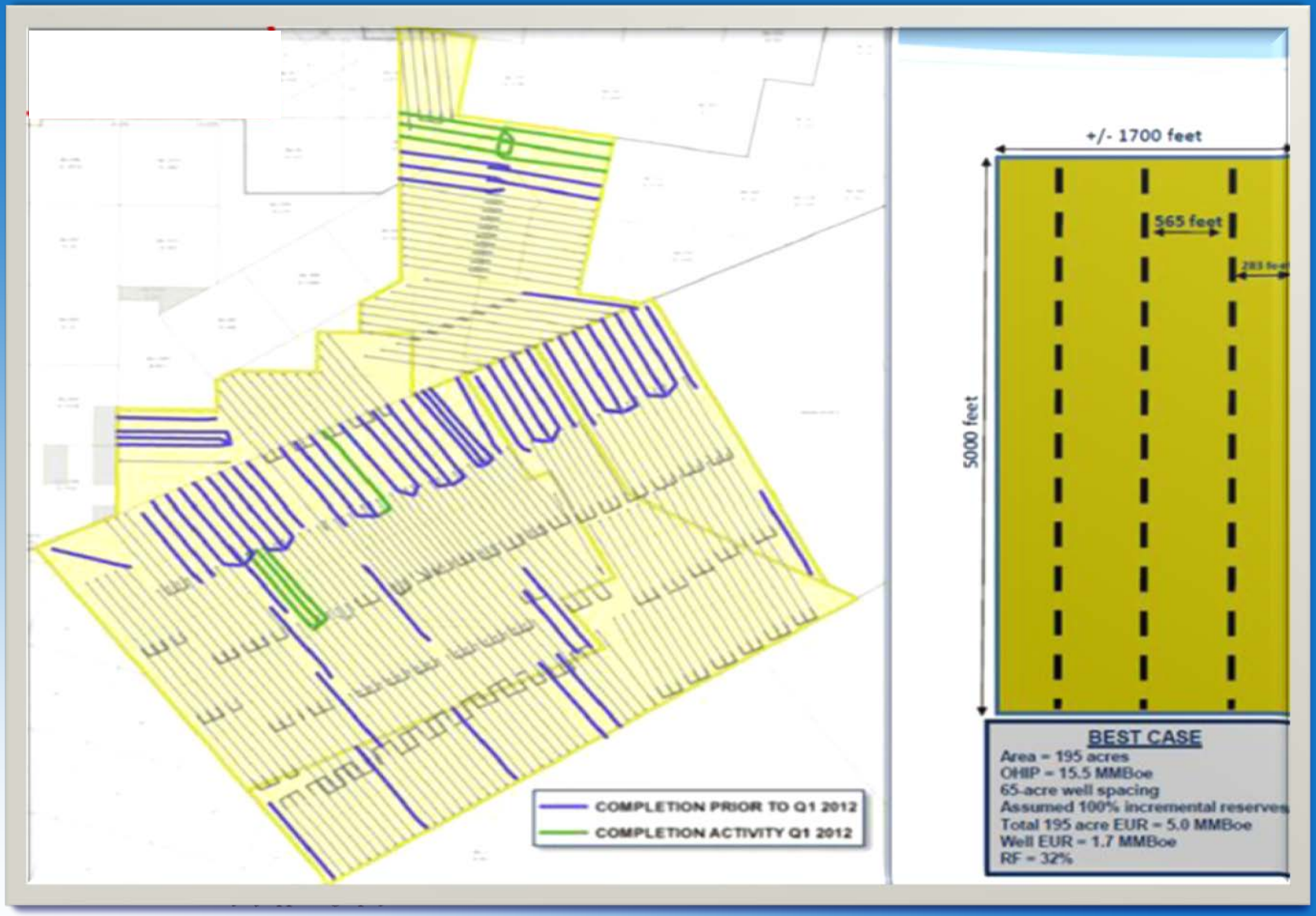
Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

Growing Shale Significance 页岩气增长显著
U.S. Natural Gas Production, 1990 - 2035

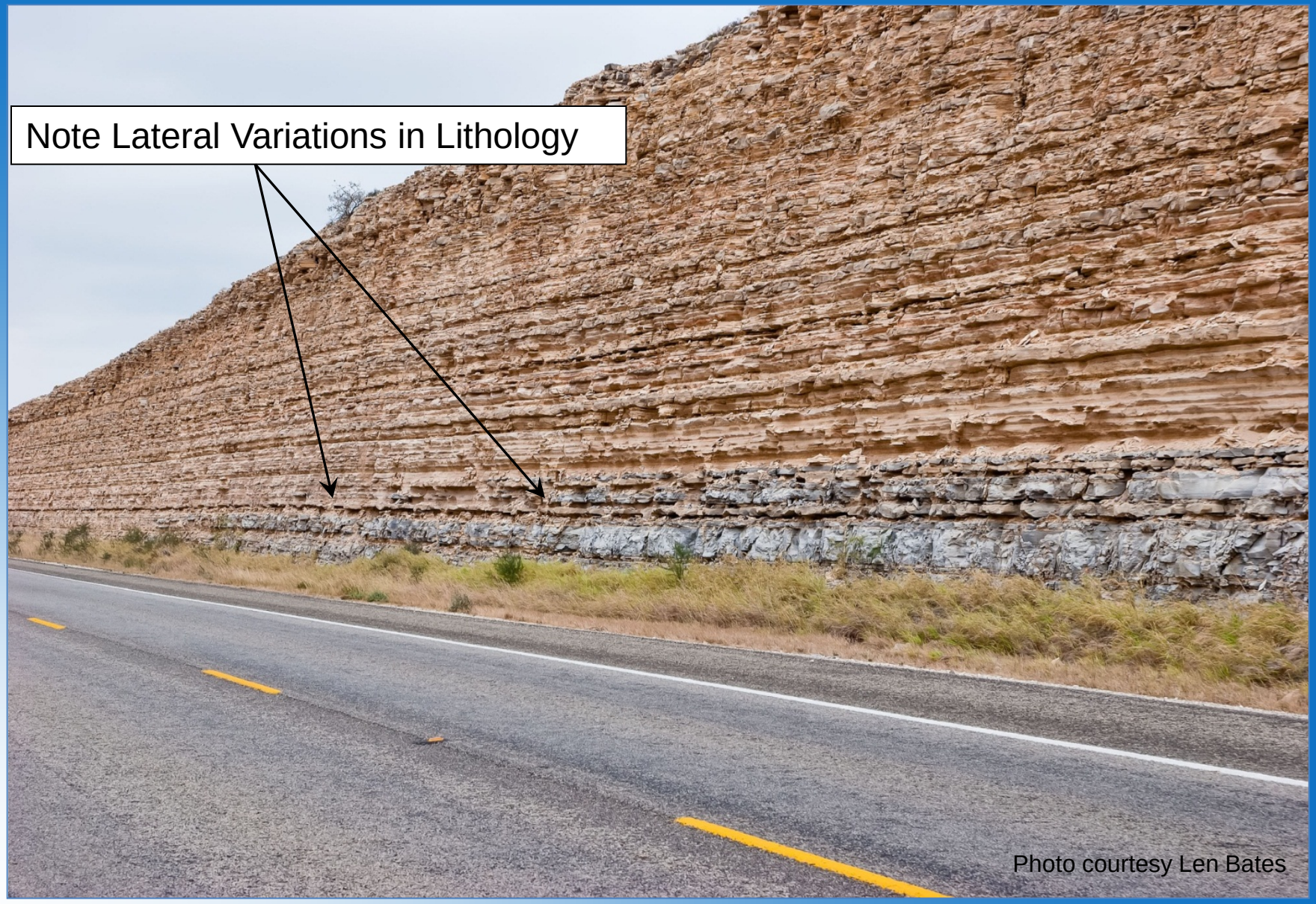


US EIA, AEO2012

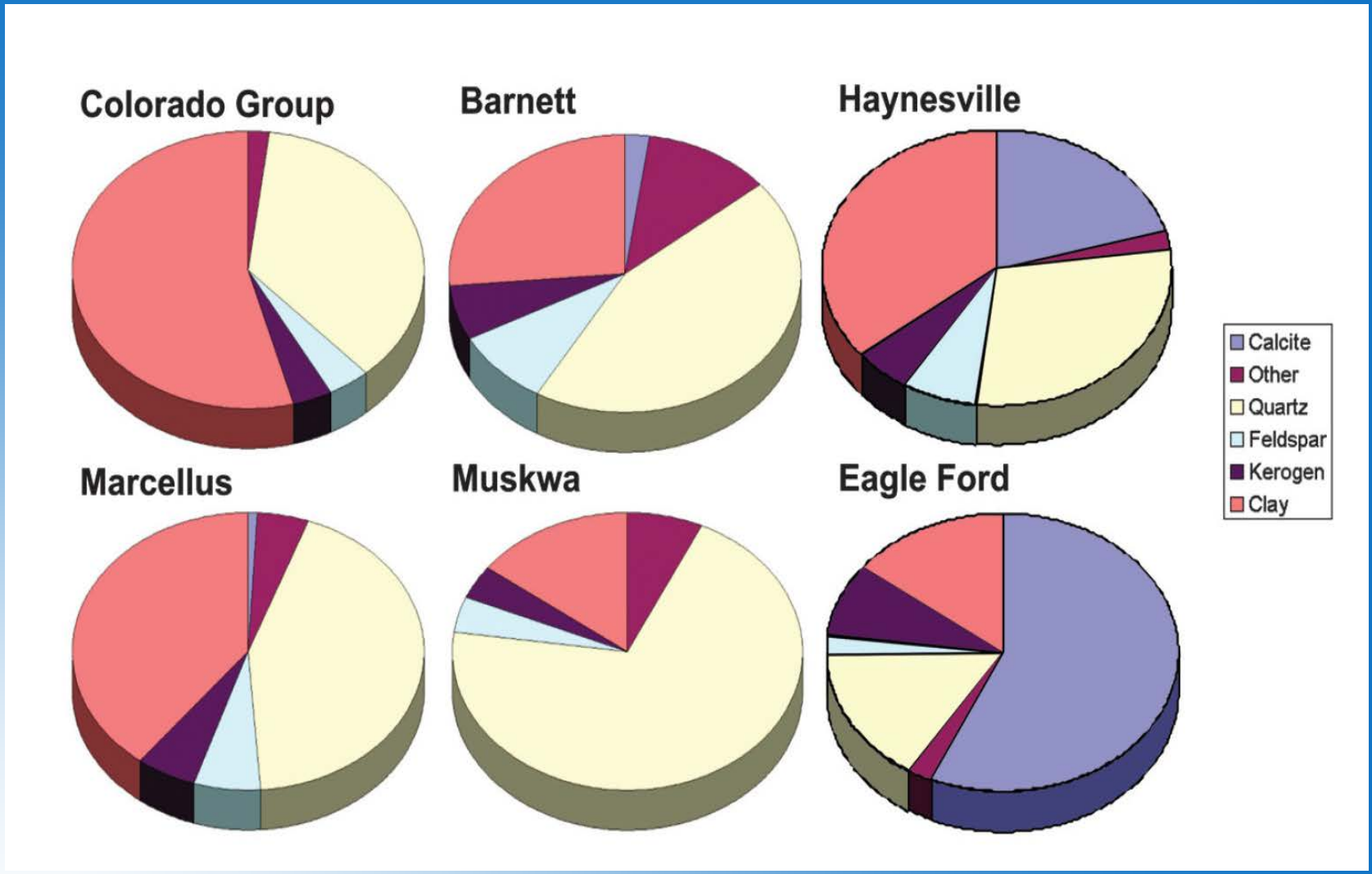
Statistical Drilling Program
统计钻井程序



Eagle Ford Shale - Lateral Heterogeneity



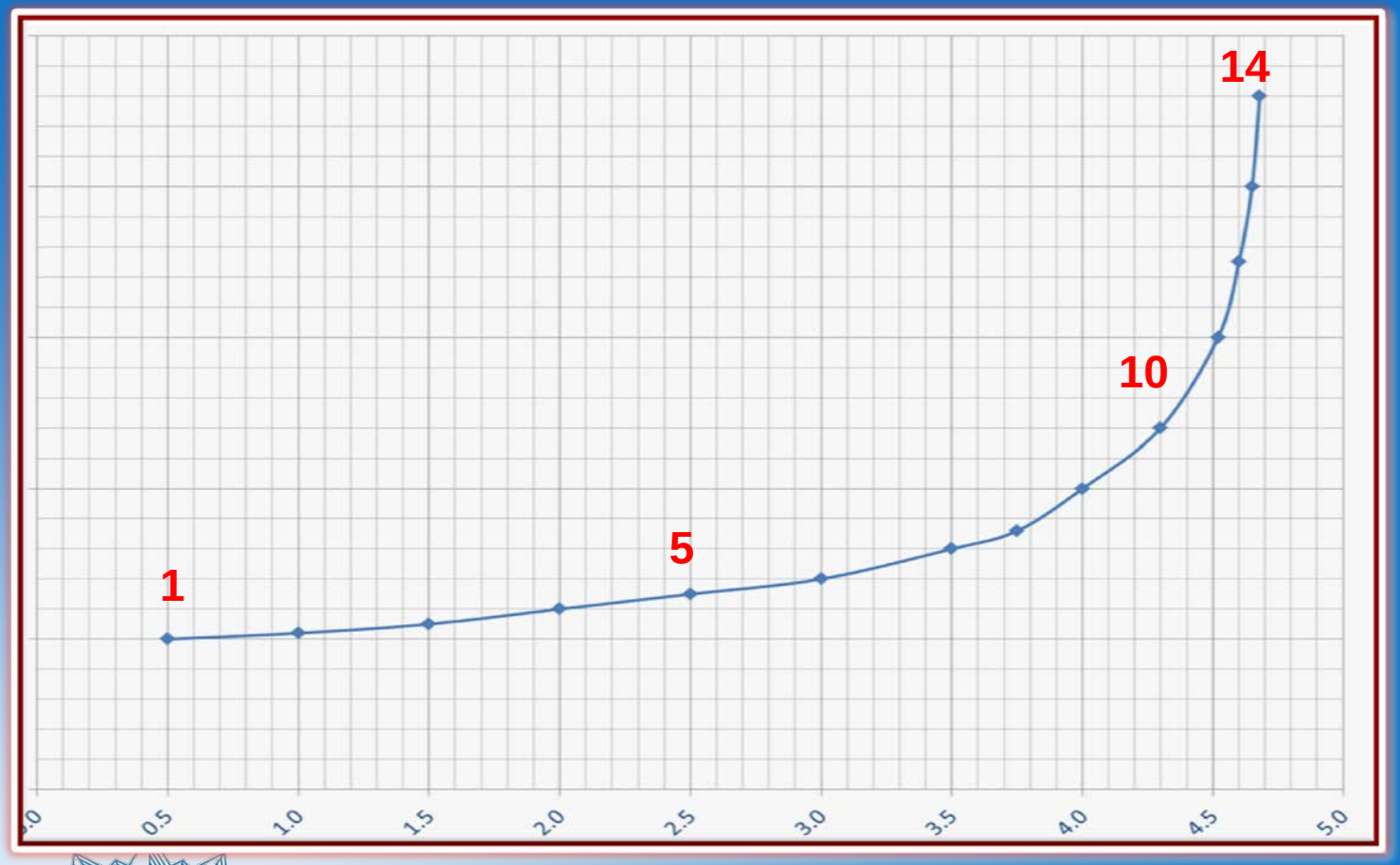
Mudrocks Mineral Composition
泥岩 礦物成份



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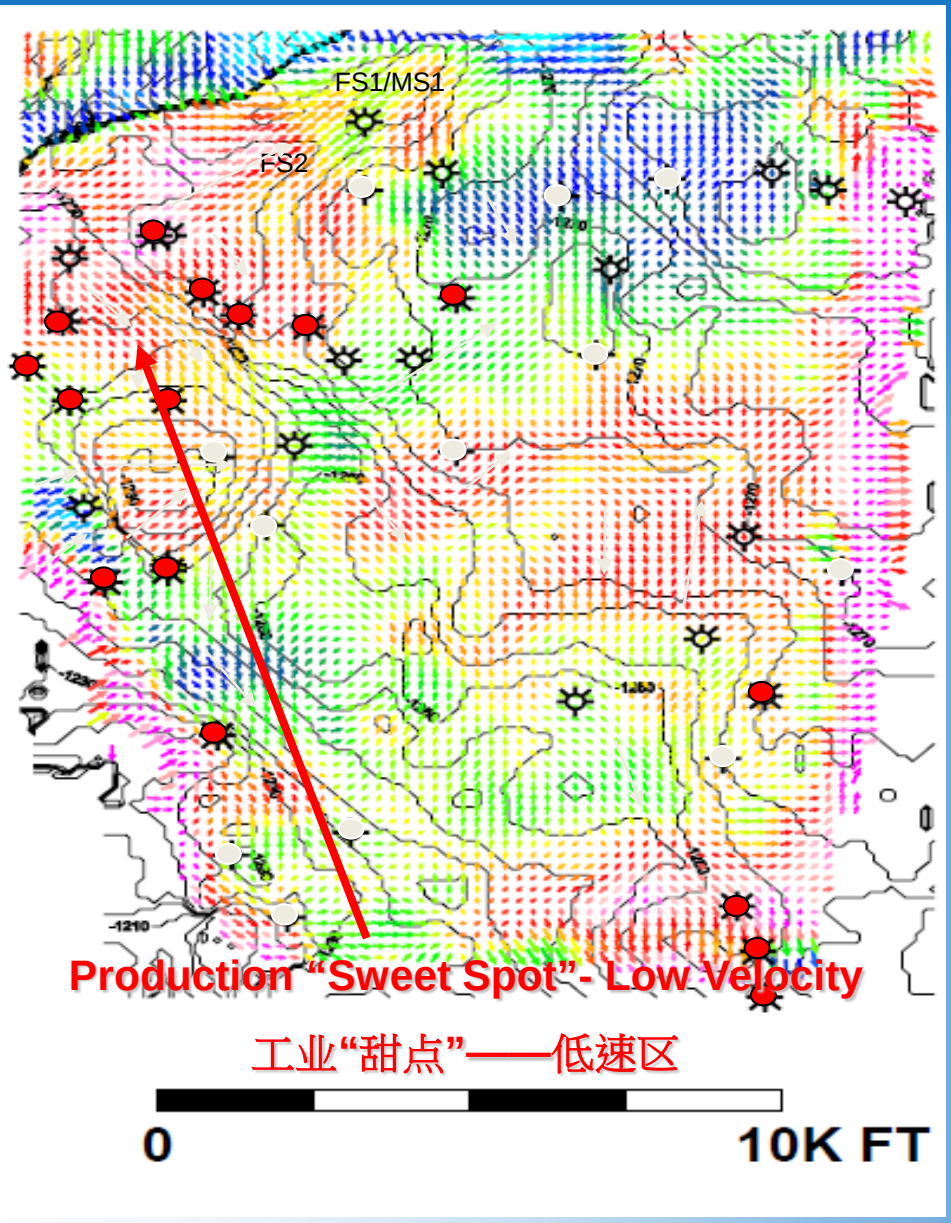
Hart et al. 2013

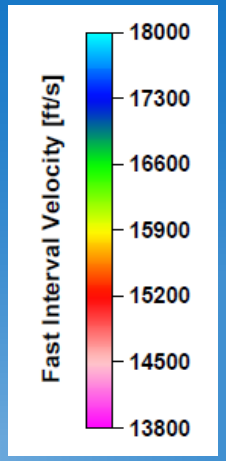
Typical Fracking Stages vs. EUR



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Smart Drilling Program
智能钻井程序





Worst Producers
Medium Producers
Best Producers

P-Wave Azimuthal Velocity Map
纵波方位速度分布图

- Arrow Direction = Fracture Direction
  箭头所指方向为裂缝方向
  - V Fast Direction V_{fast}方向
- Length of Arrow = Anisotropy Indicator
  箭头长度指示各向异性强度
  - V Fast – V Slow
- Color = V Fast Interval Velocity
  颜色代表层间速度V_{fast}

Fracture patterns change rapidly!
裂缝样式变化迅速！

YS Simon, UH Thesis, 2005.

Shale Sweet Spots
页岩甜点

Seismic Inversion for Acoustic & Elastic Parameters

Low density 低密度

Low P-impedance 低纵波阻抗

High Gamma Ray
高伽玛射线强度

High anisotropy 高各向异性

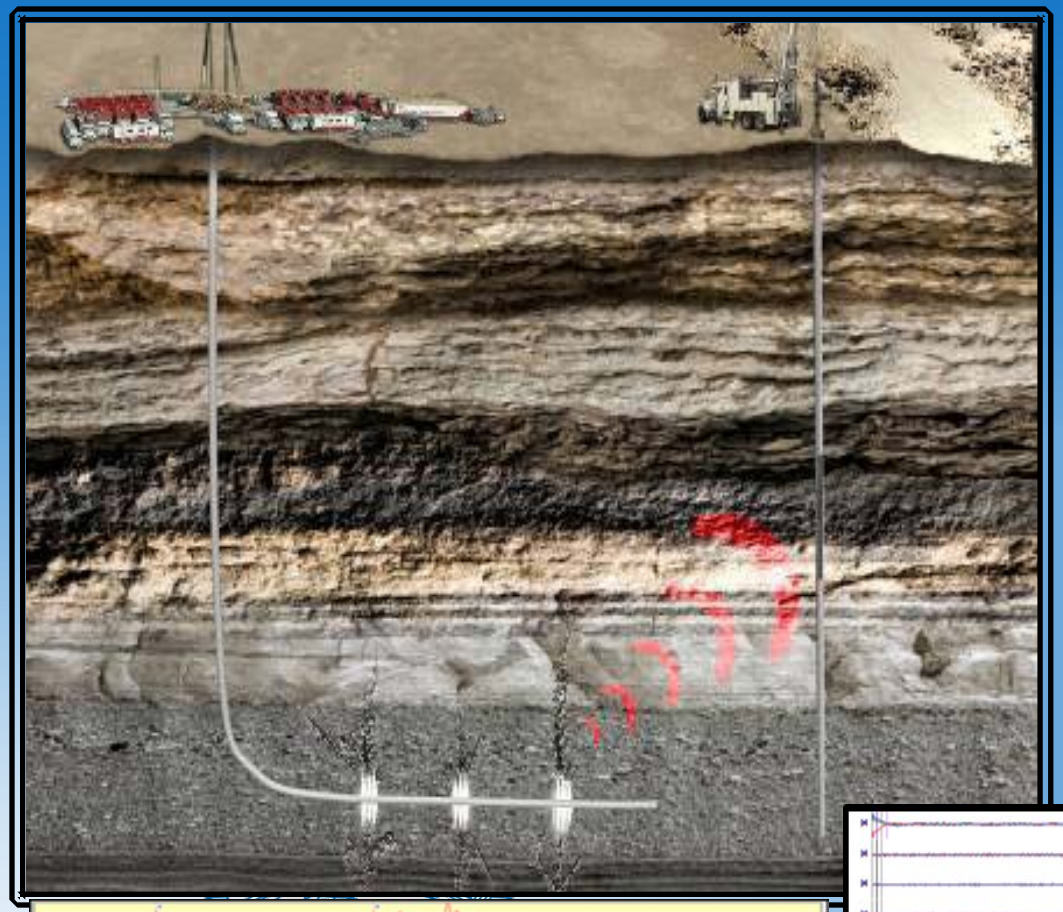
Low horizontal stress ratio
低水平应力比

Low Poisson's Ratio 低泊松比

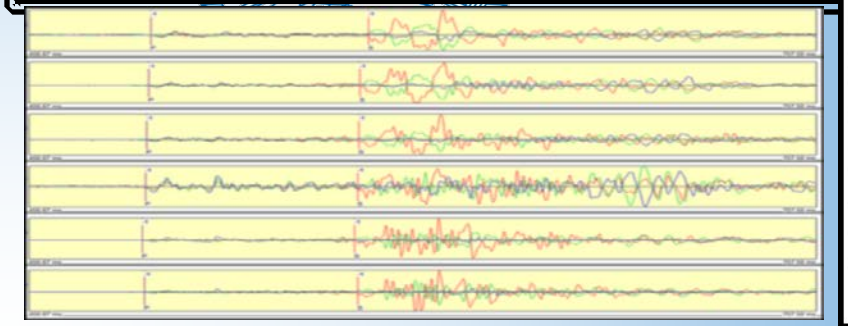
High Young's Modulus
高杨氏模量

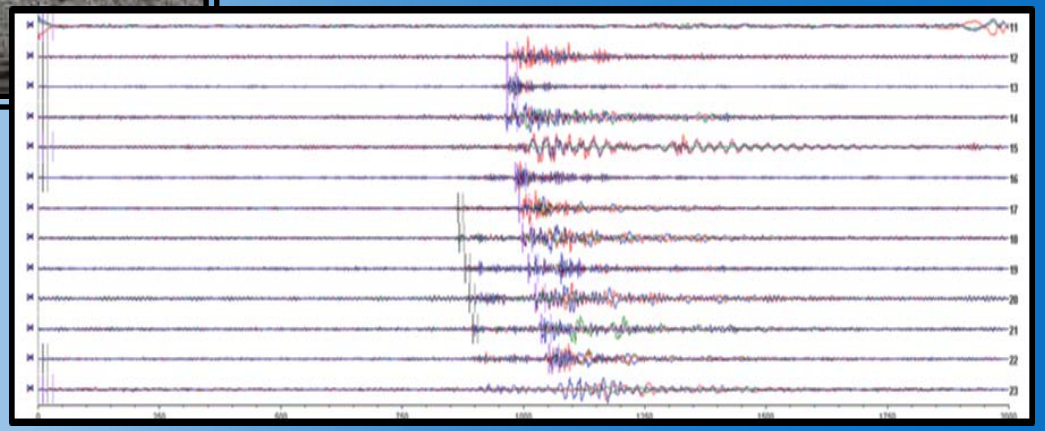
Low horizontal effective stress
低水平有效应力

Downhole Monitoring
井中监测

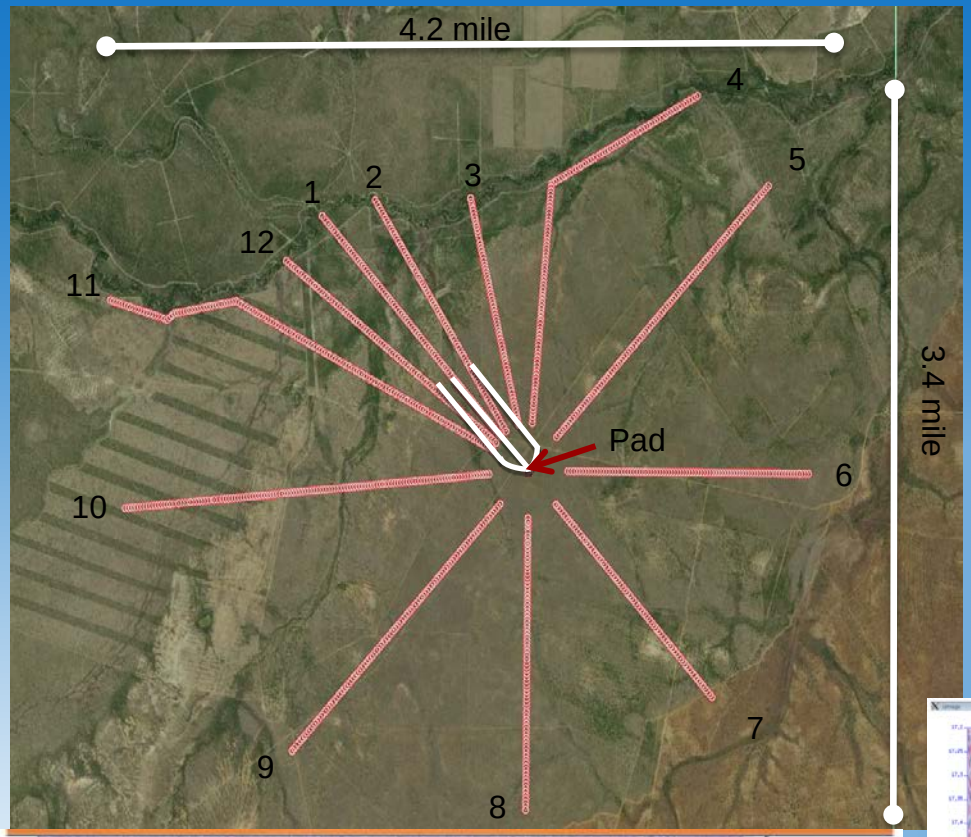


- **Deploy 8-16 three-C geophones in monitor well**
  在监测井中部署8-16个三分量检波器
- **Record P- and S-waves**
  记录纵波和横波
- **Analyze P- and S-wave moveout and timing difference.**
  分析纵波和横波 动校正时差
- **How about > 40 sensors?**
  如果传感器个数多于40个呢？

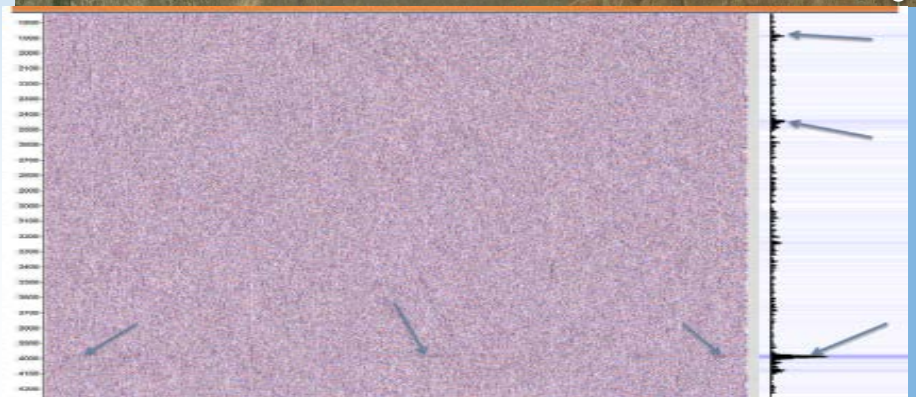


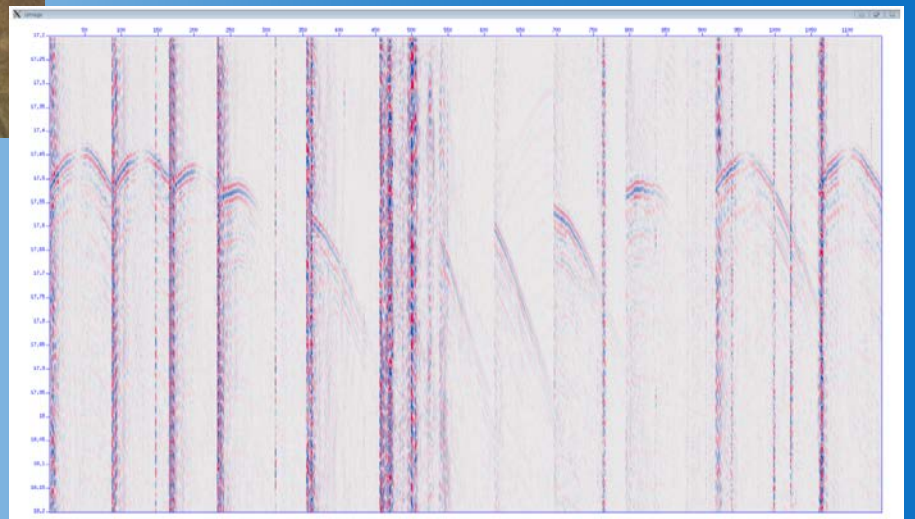


Surface Geophone Array 地表检波器排列



- **10-12 geophone lines**
  10-12 测线
- **lines radiating from the pad**
  测线从平台中心向个方向伸展
- **1,000 – 1,200 single component geophones over ~20 mi²**
  每20英里大约1000-1200个单分量检波器
- **Analyze P-wave arrival times; no shear waves**
  分析P波到达时间，不存在横波





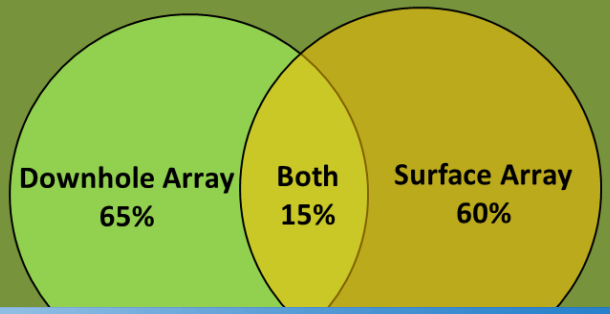
Surface vs. Downhole Recordings of Microseismics
地面vs.井中记录

Are events seen equally by downhole and surface arrays?

Identify events by Time that Microseismic Event Occurred

Cochina East 13H recorded 3788 unique events

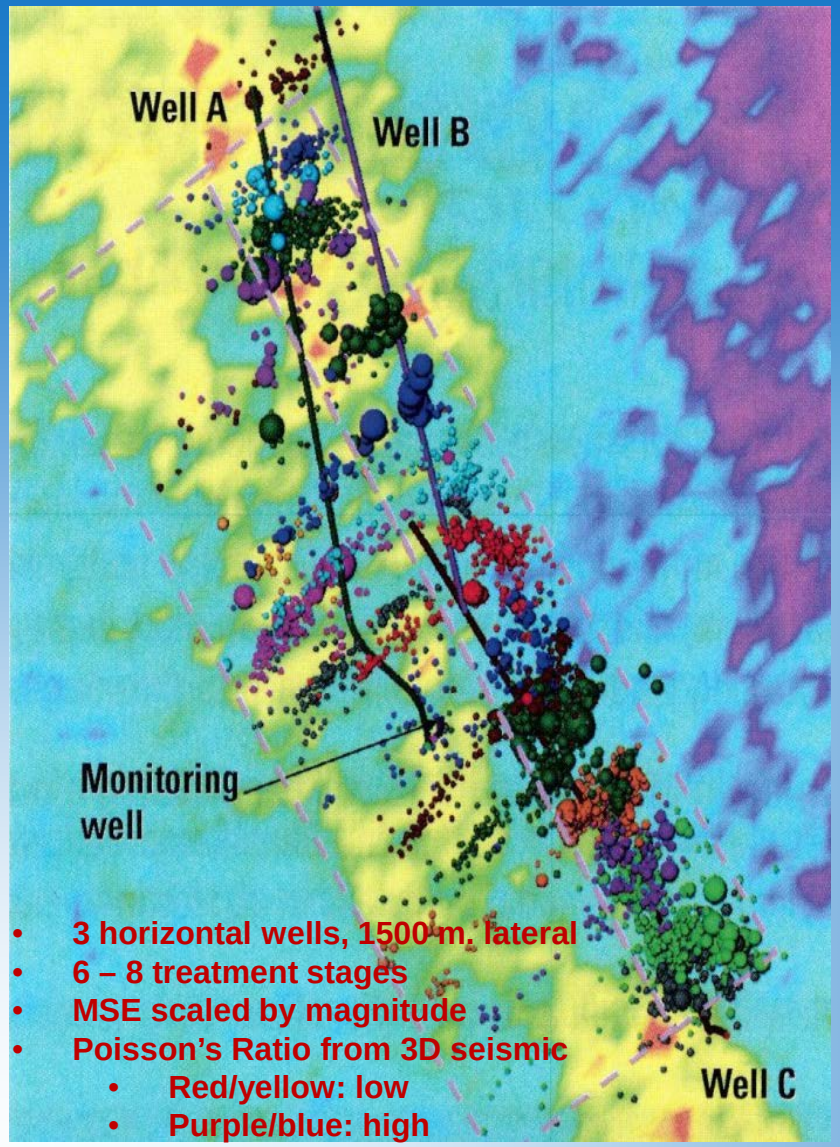
659 (15%) identified as being same event recorded by FracStar and downhole array



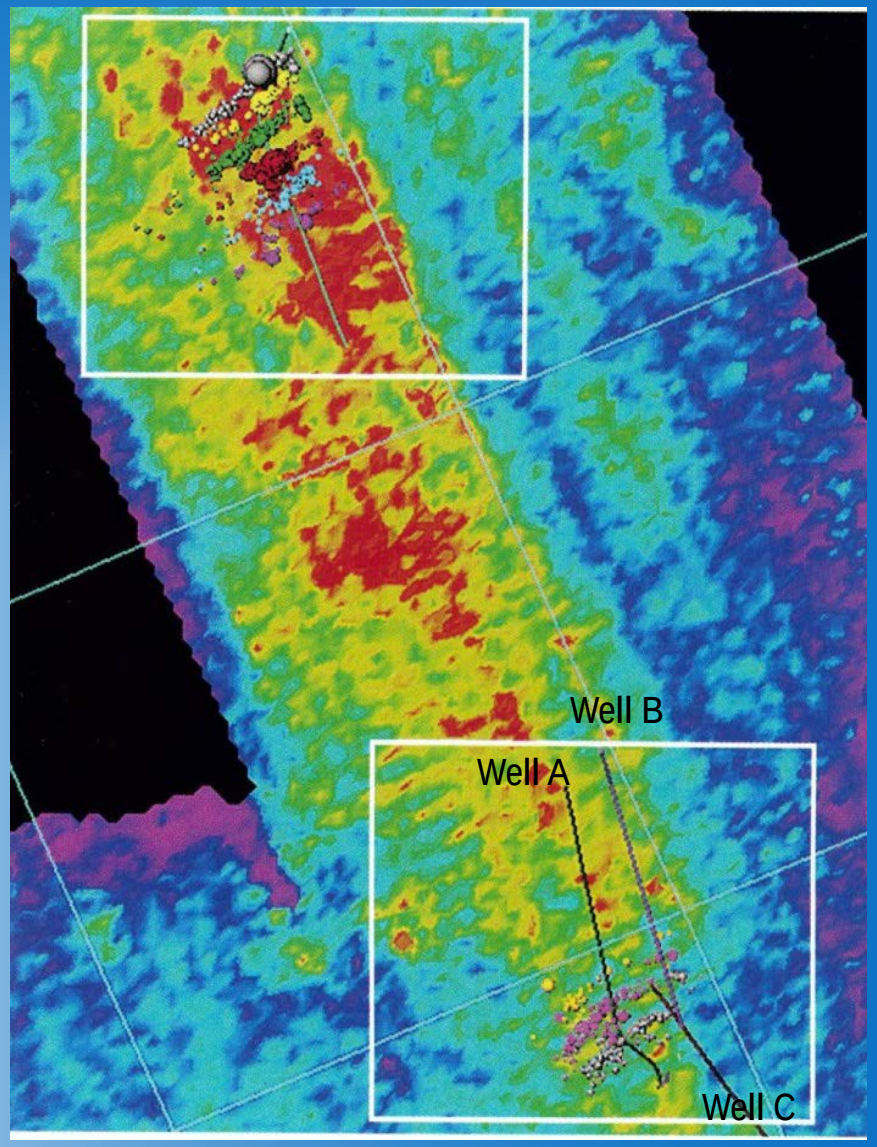
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Microseismic Events in Montney Shale
Montney Shale 微地震记录



- 3 horizontal wells, 1500 m. lateral
- 6 – 8 treatment stages
- MSE scaled by magnitude
- Poisson's Ratio from 3D seismic
  - Red/yellow: low
  - Purple/blue: high



Norton & Maxwell 2013

Information Content of Microseismic data
微地震数据内容提纲

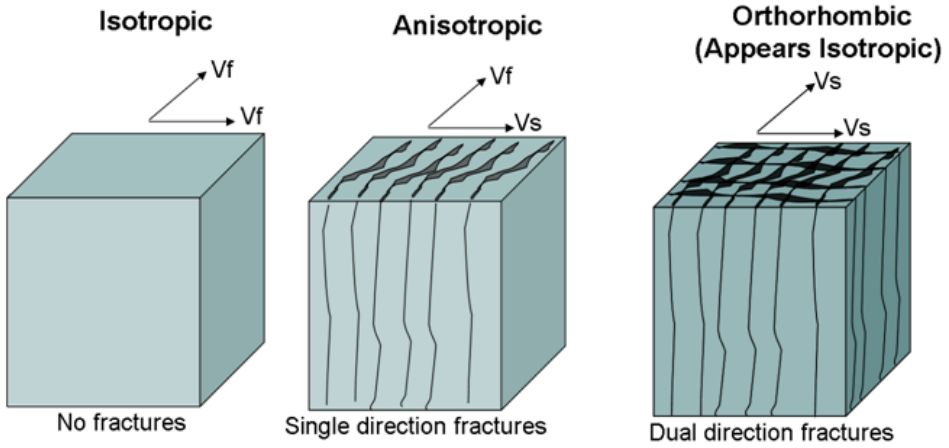
- **Stimulated reservoir volume (SRV)?**
  产生储层体积？
- **Hypocenters ~ fractured locations?**
  震源~裂缝位置？
- **Fracture mechanism?**
  裂缝机理？

- **Estimate stimulated fracture height and width**
  估计产生裂缝的高度和宽度
- **Optimize well spacing**
  优化井间距
- **Fine tuning parameters of completion procedure**
  完井程序中的协调参数
- **Evaluate the efficiency of hydraulic stimulated fracturing process**
  评价水压产生裂缝过程的效率
- **Locate buried faults**
  定位埋藏断层
- **Minimal horizontal stress orientation**
  最小水平应力方向

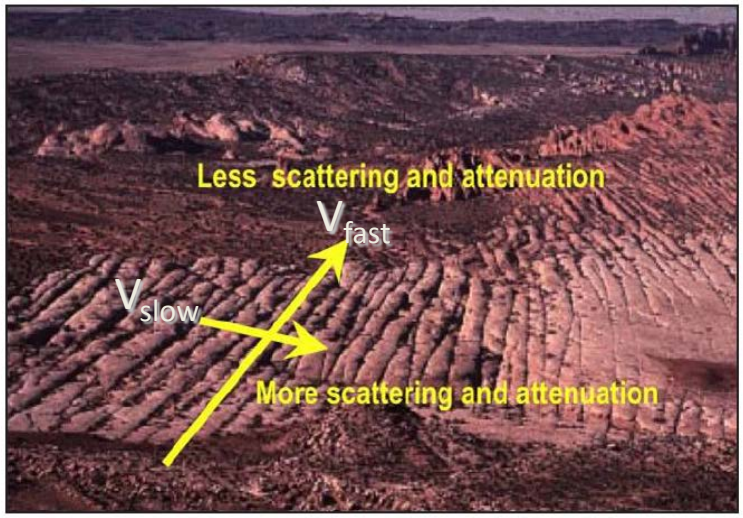


Fracture Prediction: Anisotropy
裂缝预测：各向异性

- Vertical fractures => change in seismic velocities parallel and perpendicular to fractures
  垂直裂缝=>平行和垂直裂缝方向上的速度变化
- Characterize fractures using: 描述裂缝的特征：
- Wide or multi azimuth 3D seismic 宽/多方位角3D数据
  1. Mode conversion (P-wave/S-wave) 3D 模型转化（P波/S波）的C数据
  2. 3D VSP



Variation in velocity with source-receiver azimuth

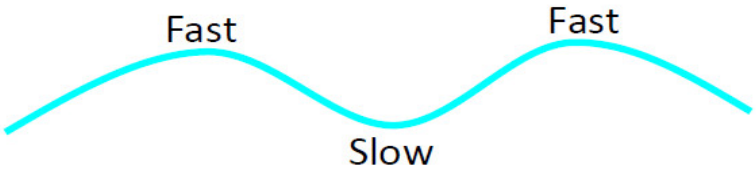


Anisotropic Velocity Analyses

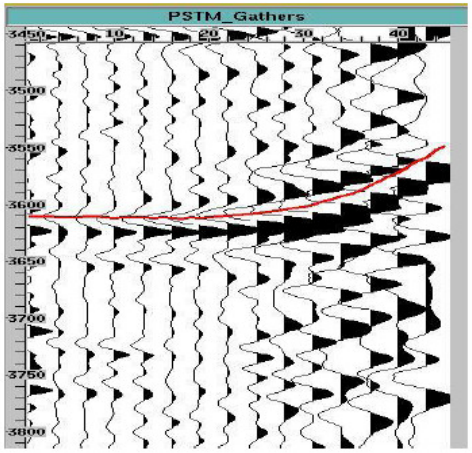
VTI
Layer Anisotropy

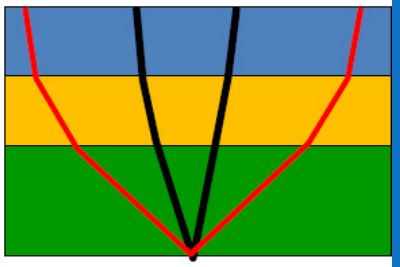
V_{fast} vs. V_{slow}
V_{max} vs. V_{min}
$(V_{max} - V_{min}) / V_{max}$
Vector orientation

HTI
Azimuthal Anisotropy

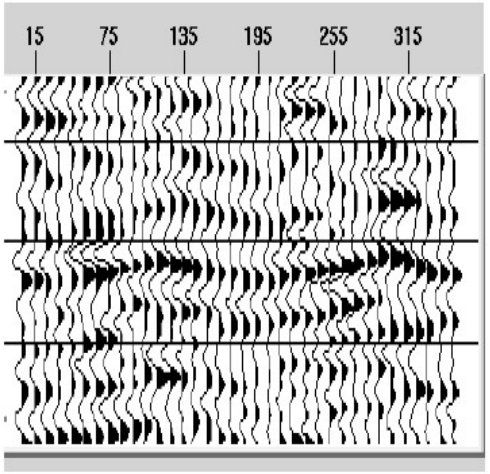


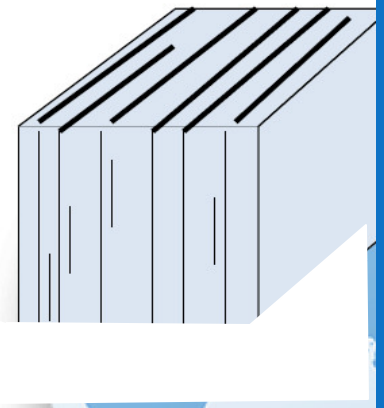
Offset





Azimuth





3D Seismic Data for Fracture Detections
三维地震数据裂缝检测

- **Wide-azimuth data acquisition** 宽方位角数据采集
  - Legendary 3D seismic data? 传统三维地震数据？
- **Full azimuth data processing** 全方位角数据处理
  - Refraction and residual static corrections
    折射和剩余静校正
  - Azimuthal processing 方位角处理
  - VTI & HTI velocity analyses VTI、HTI介质速度分析
  - Orthorhombic pre-stack migration (PSTM)
    正交各向异性叠前偏移
- **Fracture estimation** 裂缝识别
  - Azimuthal velocity estimation, V_{fast} vs. V_{slow}
    方位角速度估计， Vfast vs. Vslow
  - Minimal horizontal stress orientations
    最小水平应力方向



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Elastic Inversion from 3D Seismic Data

三维地震数据弹性反演

- **Simultaneous elastic inversion for rock properties**
  岩石参数同时弹性反演
  - **P-impedance (Z_p), S-impedance (Z_s), and Density (ρ)**
    P波波阻抗 , S波波阻抗, 密度
  - **V_p, V_s, V_p/ V_s**
  - **λρ vs. μρ**
  - **Poisson's Ratio** 泊松比
  - **Young's Modulus (E)** 杨氏模量
- **In-situ stress field** 应力场
  - **Vertical stress** 垂直应力
  - **Maximum horizontal stress** 最大水平应力
  - **Minimum horizontal stress** 最小水平应力
  - **Pore pressure** 孔隙压力
  - **Horizontal stress ratio** 水平应力比

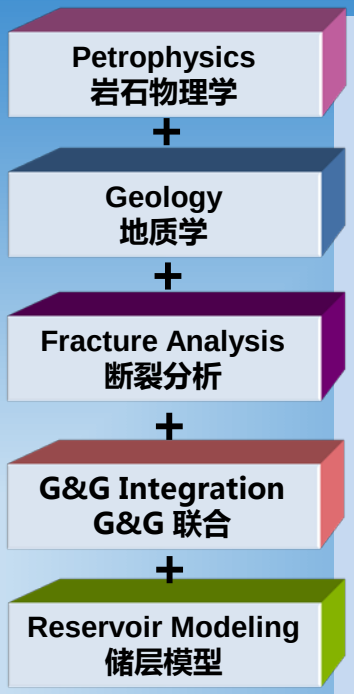


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Shale Technology Integration
页岩技术集成

- **Apply learning from data acquisition through production**
  在数据采集到生产过程中学习
  - **Utilize pilot drilling program to capture data and evaluate results**
    利用导向钻井项目采集数据和评估成果
  - **Real time application** 实时处理



- Core data, logs, porosity, permeability
  岩心数据，测井数据，孔隙度，渗透率
- Fluid properties, target window
  流体性质，目标窗口
- Rock mechanics, fluid flow
  岩石力学，流体流量
- Seismic Integration, horizontal targeting
  地震联合，层位标定
- Performance Analysis – EUR determination & production forecasting
  技术性能分析 --- 估算最终储量 & 产量预测

→ ***Technical Success***
技术上成功

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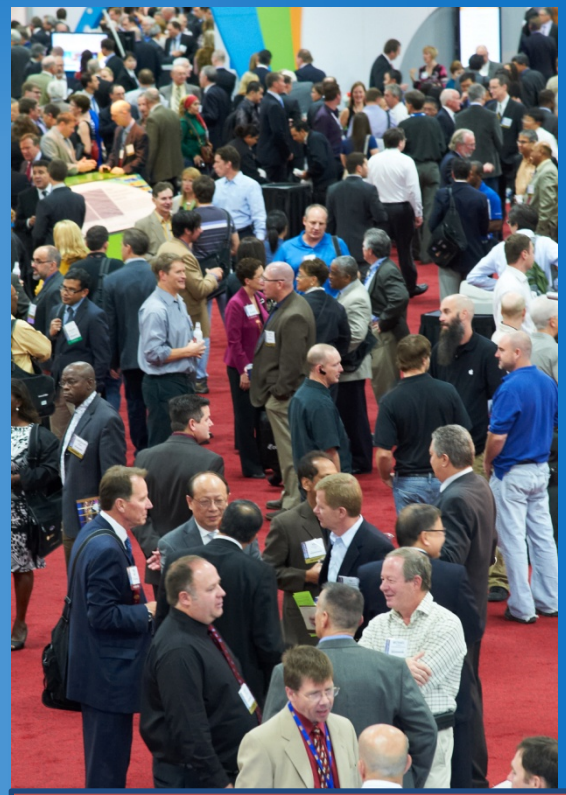
The role of SEG
SEG的角色

- **SEG is the pipeline between it's members for transfer ideas and new technology, and allows communication of new ideas.**
  SEG是会员彼此交流想法与新技术、新理念的管道
- **SEG is a technical enabling organization where the purpose is to facilitate access to geophysical knowledge.**
  SEG是以提供地球物理知识为宗旨的组织
- **How does SEG do that ?**
  SEG通过什么做到的？

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Knowledge Sharing through Meetings
会议&论坛

- **Annual Meeting is largest meeting of geoscientists in the world!**
  SEG年会是全球最大的地球科学盛会
  - **8,412 attendees** *8,412名参会者*
  - **320 exhibitors** *320名参展商*
  - **576 oral presentations** *576个口头报告*
  - **184 posters** *184个张贴报告*
  - **150 E-posters** *150个电子张贴报告*
  - **1,260 booths** *1,260个展位*



SEG Las Vegas, 2012

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Knowledge Sharing through Publications
出版物

- **THE LEADING EDGE**
  勘探前沿
- **GEOPHYSICS**
  地球物理学
- **INTERPRETATION**
- **Reference books**
  专业参考书籍
- **SEG eBooks**
  电子图书



SEG

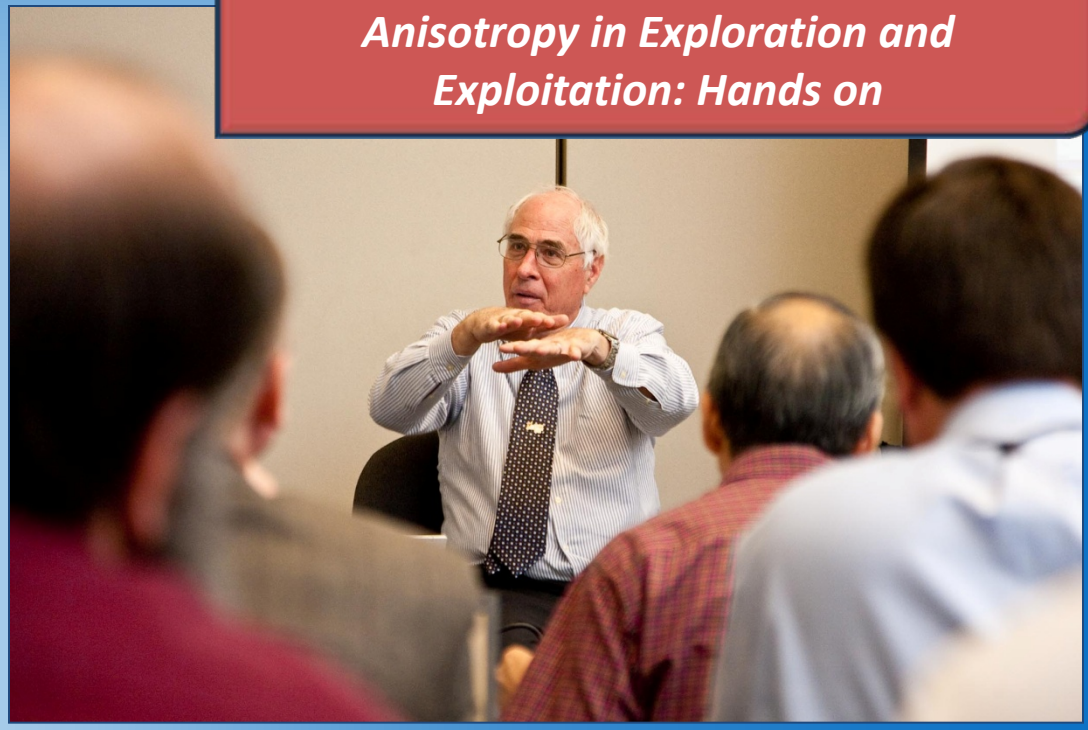
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Knowledge Sharing through Education
教育服务

- **51 CE courses currently in curriculum**
  51个可选课程
- **Public and contract**
  公开课程与协议课程
- **SEG DISC**
  杰出讲师短期课程
- **eLearning**
  在线教育课程

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SEG China 2013 Activities
2013 SEG中国活动

- **IPTC 2013** *2013 国际石油技术大会*
  - *March 26-28, Beijing International Convention Center*
- **China Student Chapter Leaders Meeting & Challenge Bowl**

  中国学生分会会议&挑战杯竞赛
  - *April 17-19, China University of Petroleum*
- **SEG Board of Director Special Lecturer Tour** *SEG董事特别名誉讲座*
  - *May 27-31, October, 17 SEG Student Chapter*
- **SEG Asia-Pacific Near Surface Conference** *亚太区近地表地球物理会议暨展览*
  - *July 17-19, Beijing International Convention Center*
- **Stanford-USTC-MIT (SUM) Geophysics Faculty Forum** *斯坦福-中科大-麻省理工三校教授地球物理讲习班, Early September, USTC meeting room*
- *“東方杯”大學生堪探地球物理大賽, October 25-27*
- *第二屆地球物理學生論壇, October 29*

Knowledge Sharing through SEG Online
SEG在线服务

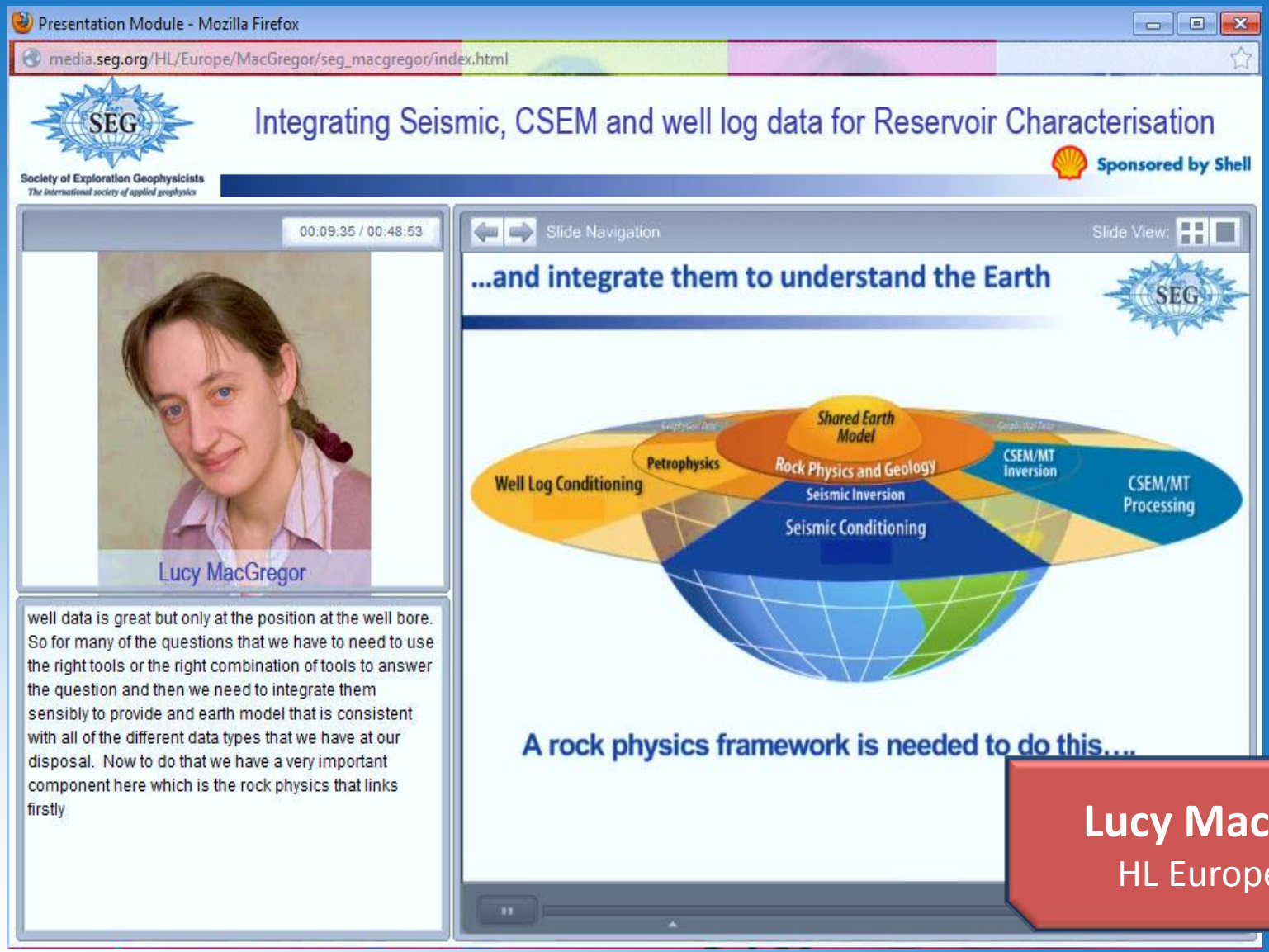


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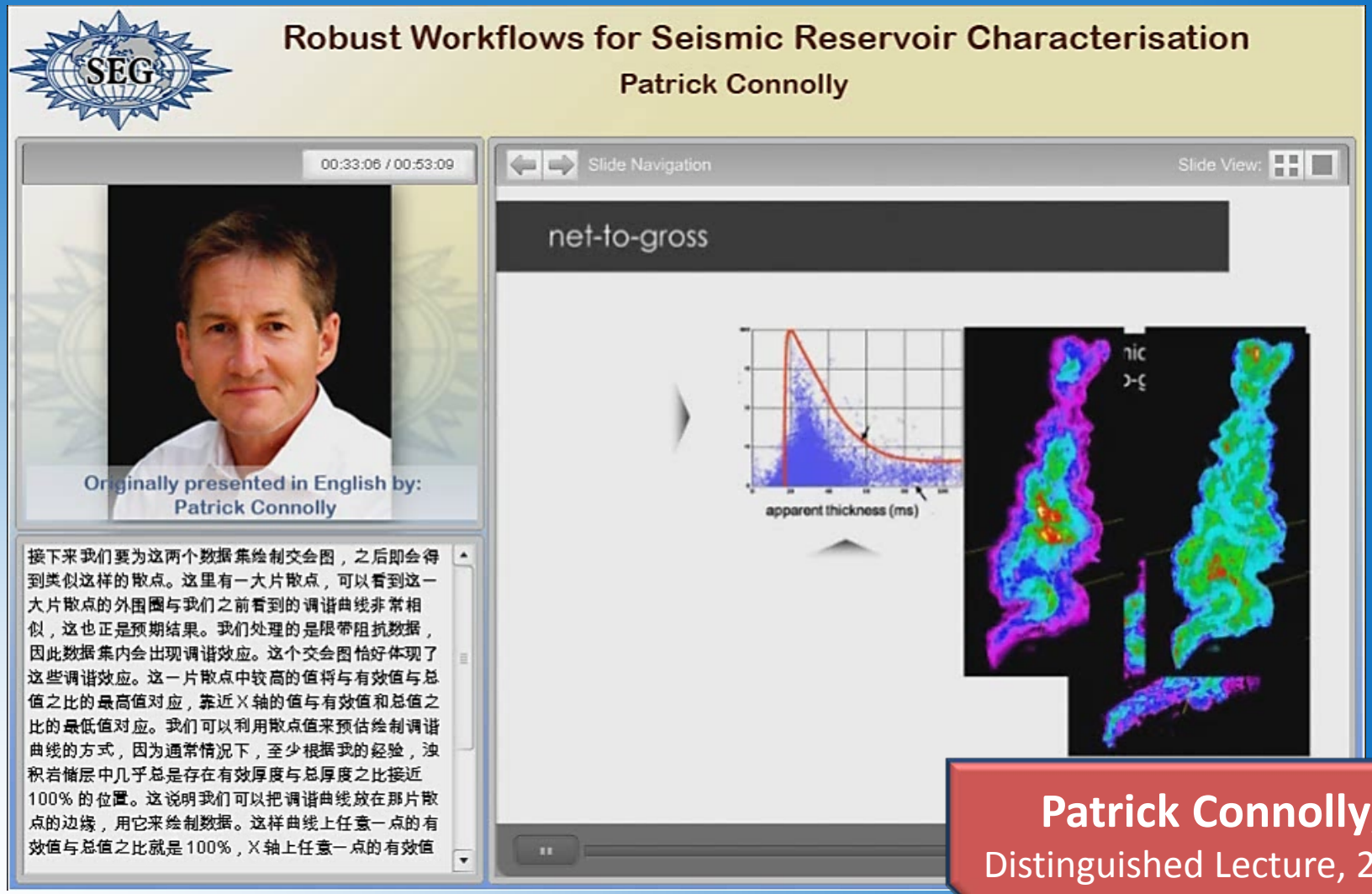
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Online Lectures
在线讲座



Lucy MacGregor
HL Europe, 2011

Online Translations
在线资源翻成中文



Patrick Connolly,
Distinguished Lecture, 2010

The engine that drives SEG
推动SEG的动力

SEG Foundation:

Funding innovative activities and grant programs that benefit geophysicists, their professional community, the SEG and the general public

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资助创新活动，并支持对地球物理学家培养，建立地球物理学平台，SEG及公众有益的项目



SEG Thanks our Leadership Investors
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Online Learning

CNPC

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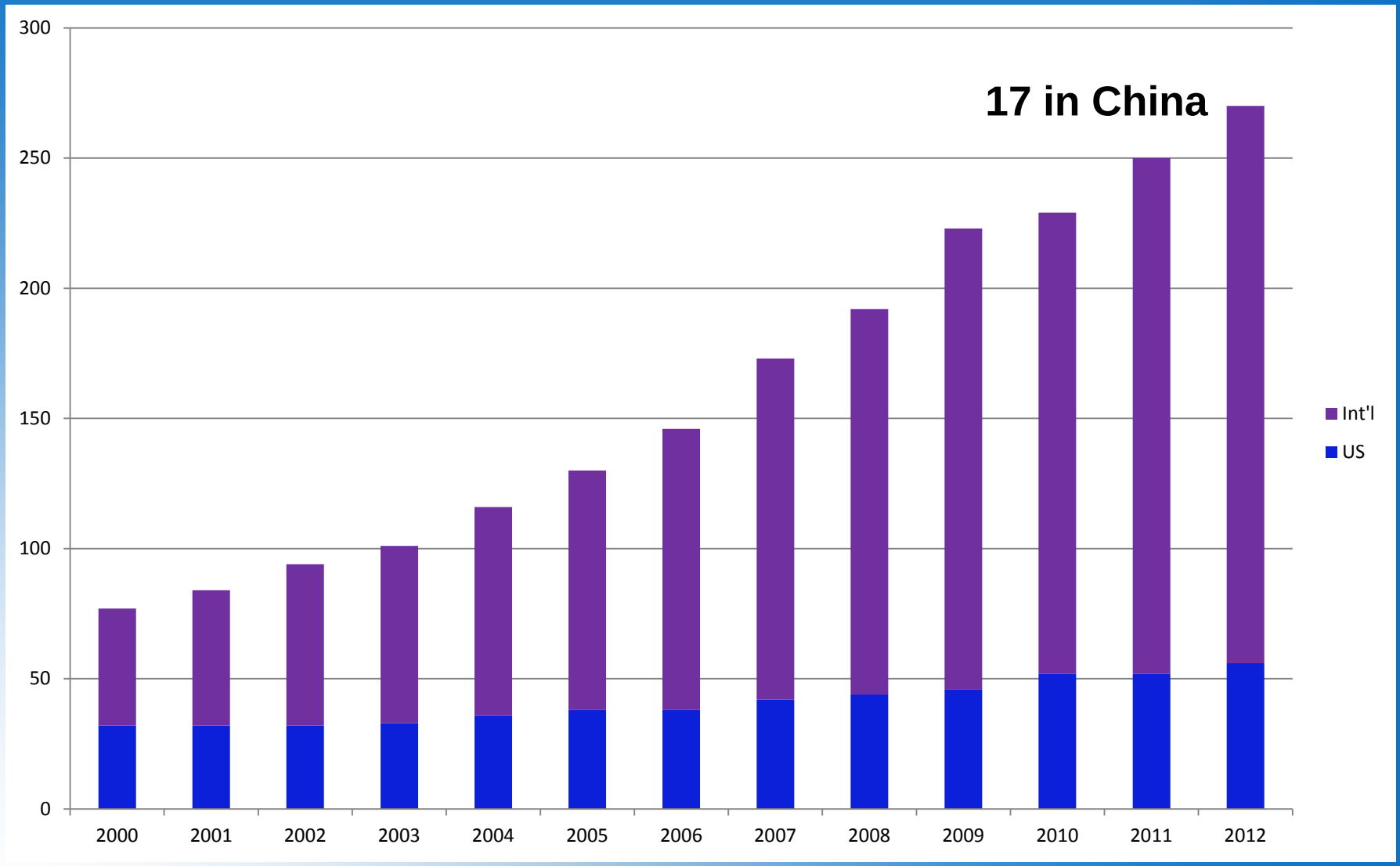
University and Student Programs
大学与学生项目





- Sponsored Membership 免费学生会员
- **Student Chapter Programs 学生分会项目**
- **Student Leadership Symposium 学生领导力讨论会**
- **Student Education Program 学生教育项目**
- Challenge Bowl 挑战杯竞赛
- Scholarships 奖学金
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Student Chapter Growth
学生分会增长



SEG/Chevron Student Leadership Symposium (SLS)
SEG/Chevron学生领导力讨论会

- 50 Student Chapter leaders each year
- Engage and inspire!
- Connect to Universities
- To date, **293** participants

Chevron

Human Energy™

2011 SLS, San Antonio



SEG/ExxonMobil Student Education Program (SEP)
SEG/ExxonMobil 学生教育项目

- 3 day course about Multi-disciplinary integration
- Fosters teamwork
- To date, **408** participants
- 3 events each year
  - Berlin 2013
  - Rio de Janeiro 2013
  - Houston 2013



2011 SEP, San Antonio

SEG University Excellence Program
SEG优秀大学项目

- Raise standard of geophysical education in universities worldwide
- Recommended Curricula
- Student Certification
- Program Accreditation



Total and CGGVeritas announce Sustaining Investments, San Antonio, 2011

TOTAL

CGGVERITAS

Presentation Outline
报告提纲

- **Recent advances in sub-salt imaging**
  盐丘下方成像的最新进展
- **Broadband seismology**
  宽带地震学
- **3D seismology for unconventional resources development**
  非常规能源开发的三维地震
- **Summaries**
  总结

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