A Review of Specialist Geoscience Technologies

Hamish Wilson, Keith Nunn, Matt Luheshi
Alan Reid, Lucy McGregor, Jannis Makris, Sue Raikes, Ian Jack

Thesis

- Most exploration is based on 2D and 3D seismic.
- Yet there are a suite of specialist technologies that can:
  - De-risk basins
  - Reduce the spend on conventional seismic through focusing spend on ‘prospective areas’
  - Reduce ambiguity in seismic interpretation and thus improve subsurface interpretation
- These technologies, when used as part of an integrated exploration approach can reduce cost and risk.
- The key is to understand what problem you are trying to solve and select the appropriate mix of technologies.

The Analysis

- Editors – Matt Luheshi, Keith Nunn and Hamish Wilson
  - Crustal studies Jannis Makris
  - Gravity and magnetics Alan Reid
  - Gravity Gradiometry Matt Luheshi
  - Marine Electromagnetic methods Lucy McGregor
  - Ocean Bottom Marine Seismic Techniques Ian Jack
  - Micro Seismic Sue Raikes

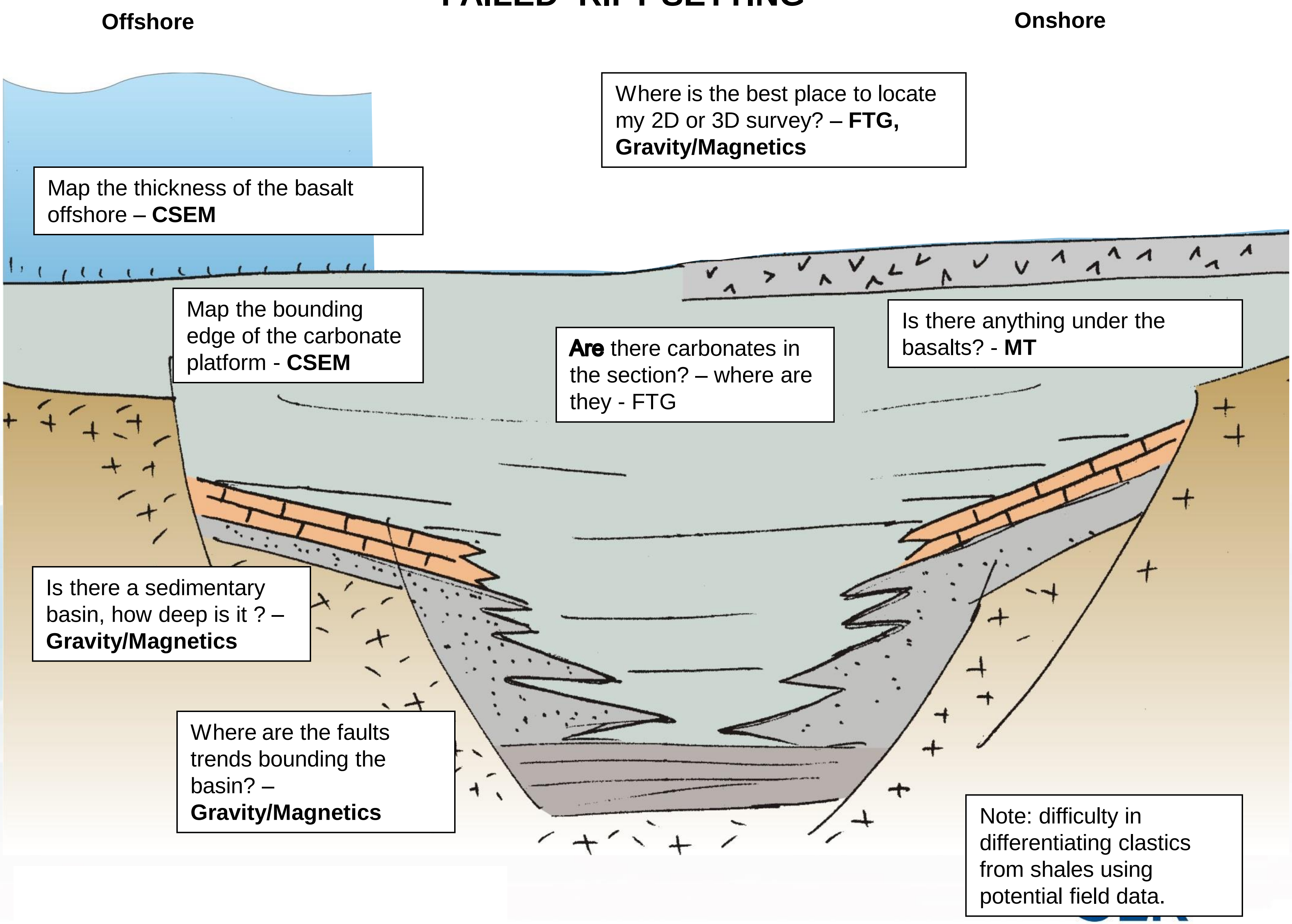
Rock Measurements

• Conventional seismic	Velocity contrast
• Gravity	Density contrast
• Magnetics	Magnetic contrast (presence of Iron)
• Electro magnetism	Resistivity contrast
• Microseismic	Movement

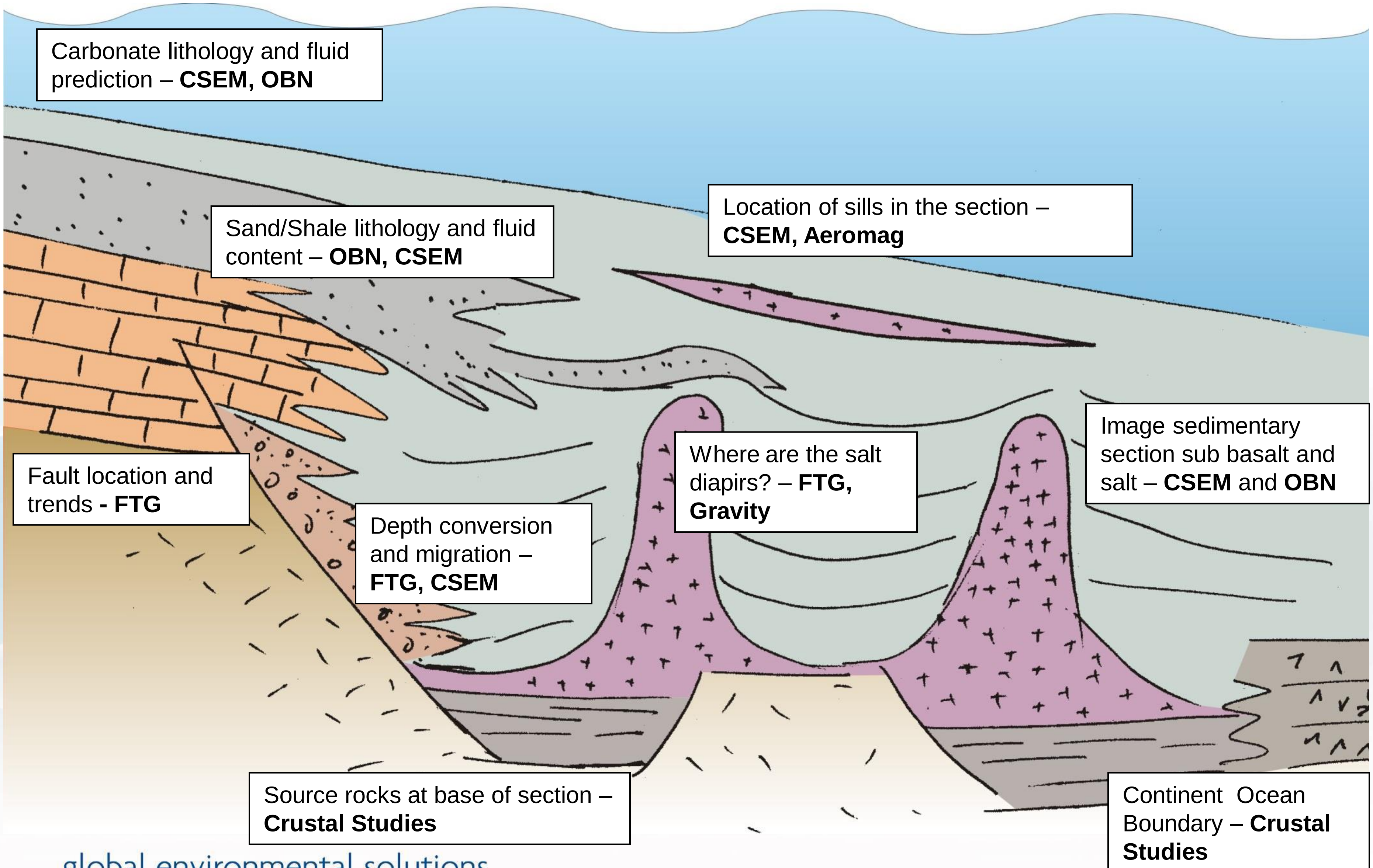
Obvious comments

1)We'll get a better answer if we measure more properties
2)We'll only get an answer if the rocks have different properties
3)The answer is only useful if it is the right resolution.

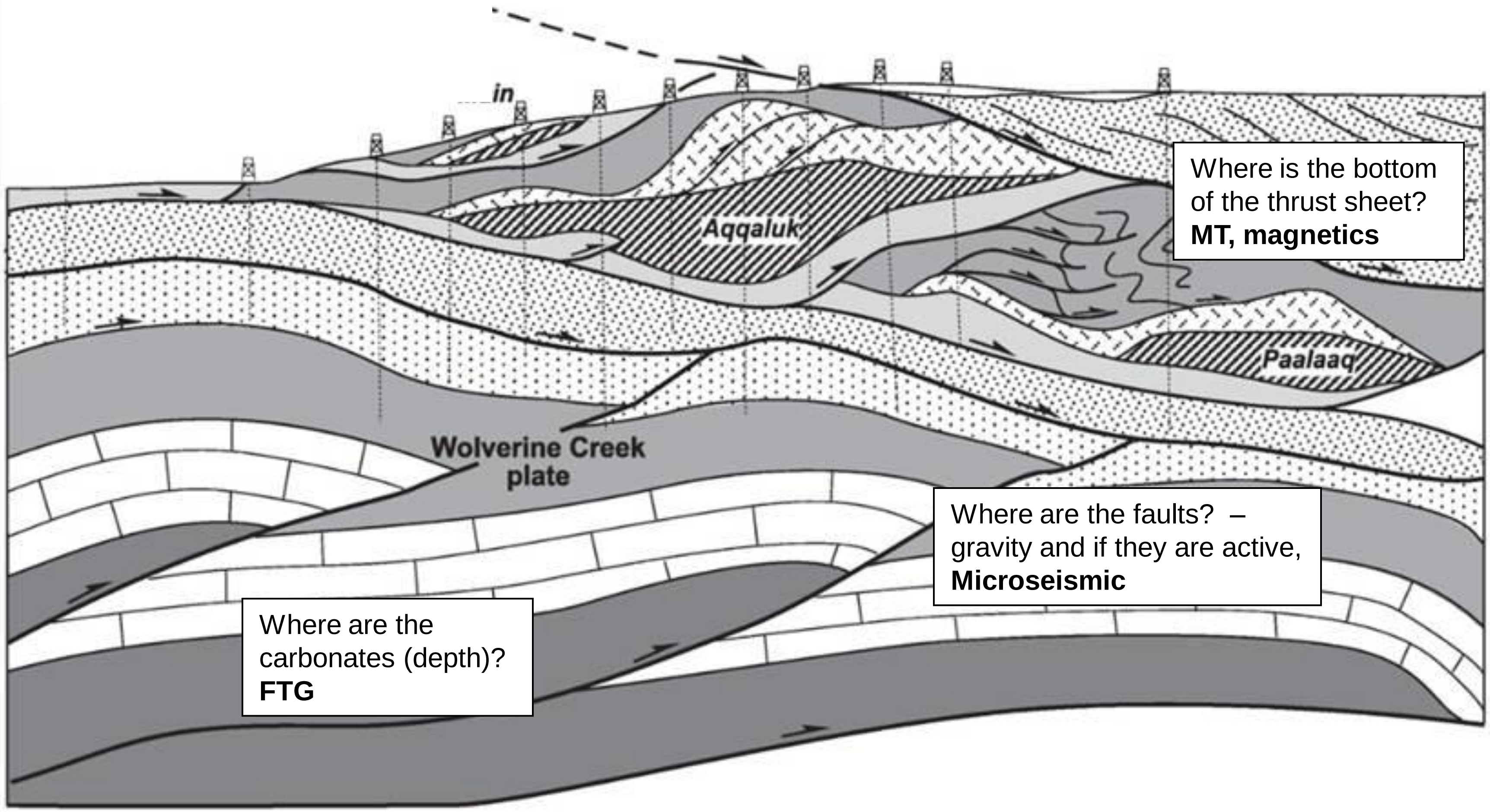
FAILED RIFT SETTING



OFFSHORE PASSIVE MARGIN SETTING



ONSHORE OVER THRUST SETTING



	Geoscience Problem
Cost $/stn deployment or well pad (*)	
Cost S/km	
Cost $/sq km	
Basin	Tectonic basin formation mechanism
	Crustal thickness
	Heat flow history
	Basin delineation
	Depth to basement
	Overthrust configuration
	Basin fabric
	Major fault delineation
Play Fairway Analysis	Fault delineation
	Cross section modelling
	Detection/delineation of volcanics
	Velocity constraints/modelling
	PSDM modelling
	Seismic migration improvement
	Imaging prospect scale features
	Clastic/salt interface
	Clastic carbonate interface
Prospect	Prospect definition
	PSDM modelling
	Prospect definition at relatively shallow depth (~<2km)
	Sub basalt imaging
	Sub Salt imaging
	Lithology prediction
	Fluid prediction
Production and Reservoir Management	Production monitoring
	PSDM modelling
	Location of old wells and pipelines
	Fault location
	Fault mobility
	Fracture orientation
	Fracture location

When should you use these technologies?

Always Consider		Partial solution- sometimes effective		Not approriate at this stage - not cost effective

	Geoscience Problem	Land 2D Seismic	Marine 2D Seismic	Land 3D Seismic	Marine 3D Seismic
Cost $/stn deployment or pad (?)					
Cost S/km		4,000-20,000	1,000-2,000		
Cost $/sq km				15,000-100,000	8,000 - 30,000
Basin	Tectonic basin formation mechanism				
	Crustal thickness				
	Heat flow history				
	Basin delineation				
	Depth to basement		Long offset		
	Overthrust configuration				
	Basin fabric				
	Major fault delineation				
Play Fairway Analysis	Fault delineation				
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	Location of old wells and pipelines				
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	Fault mobility				
	Fracture orientation				
	Fracture location				

Consider these costs – particularly on shore

	Geoscience Problem	Crustal Seismic
Cost $/stn deployment or well pad (*)		12,000-16,000
Cost S/km		3,000 - 4,000
Cost $/sq km		
Basin	Tectonic basin formation mechanism	
	Crustal thickness	
	Heat flow history	
	Basin delineation	
	Depth to basement	
	Overthrust configuration	
	Basin fabric	
	Major fault delineation	
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	Fracture location	

	Geoscience Problem	Crustal Seismic	AeroMagnetics
Cost $/stn deployment or well pad (*)		12,000-16,000	
Cost S/km		3,000 - 4,000	15-20
Cost $/sq km			
Basin	Tectonic basin formation mechanism		
	Crustal thickness		
	Heat flow history		
	Basin delineation		
	Depth to basement		
	Overthrust configuration		
	Basin fabric		
	Major fault delineation		
Play Fairway Analysis	Fault delineation		
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	Fracture location		

	Geoscience Problem	Crustal Seismic	AeroMagneti cs	AeroGravity
Cost $/stn deployment or well pad (*)		12,000-16,000		
Cost S/km		3,000 - 4,000	15-20	80
Cost $/sq km				
Basin	Tectonic basin formation mechanism			
	Crustal thickness			
	Heat flow history			
	Basin delineation			
	Depth to basement			
	Overthrust configuration			
	Basin fabric			
	Major fault delineation			
Play Fairway Analysis	Fault delineation			
	Cross section modelling			
	Detection/delineation of volcanics			
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	Fault mobility			
	Fracture orientation			
	Fracture location			

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG
Cost $/stn deployment or well pad (*)		12,000-16,000			
Cost S/km		3,000 - 4,000	15-20	80	150
Cost $/sq km					
Basin	Tectonic basin formation mechanism				
	Crustal thickness				
	Heat flow history				
	Basin delineation				
	Depth to basement				
	Overthrust configuration				
	Basin fabric				
	Major fault delineation				
Play Fairway Analysis	Fault delineation				
	Cross section modelling				
	Detection/delineation of volcanics				
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	Fluid prediction				
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	PSDM modelling				
	Location of old wells and pipelines				
	Fault location				
	Fault mobility				
	Fracture orientation				
	Fracture location				

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	MT
Cost $/stn deployment or well pad (*)		12,000-16,000				1,500-2,000
Cost S/km		3,000 - 4,000	15-20	80	150	50
Cost $/sq km						
Basin	Tectonic basin formation mechanism					
	Crustal thickness					
	Heat flow history					
	Basin delineation					
	Depth to basement					
	Overthrust configuration					
	Basin fabric					
	Major fault delineation					
Play Fairway Analysis	Fault delineation					
	Cross section modelling					
	Detection/delineation of volcanics					
	Velocity constraints/modelling					
	PSDM modelling					
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	Prospect definition at relatively shallow depth (~<2km)					
	Sub basalt imaging		??			
	Sub Salt imaging					
	Lithology prediction					
	Fluid prediction					
Production and Reservoir Management	Production monitoring					
	PSDM modelling					
	Location of old wells and pipelines					
	Fault location					
	Fault mobility					
	Fracture orientation					
	Fracture location					

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	MT	CSEM
Cost $/stn deployment or well pad (*)		12,000-16,000				1,500-2,000	
Cost S/km		3,000 - 4,000	15-20	80	150	50	2,400
Cost $/sq km							
Basin	Tectonic basin formation mechanism						
	Crustal thickness						
	Heat flow history						
	Basin delineation						
	Depth to basement						
	Overthrust configuration						
	Basin fabric						
	Major fault delineation						
Play Fairway Analysis	Fault delineation						
	Cross section modelling						??
	Detection/delineation of volcanics						
	Velocity constraints/modelling						
	PSDM modelling						
	Seismic migration improvement						
	Imaging prospect scale features						
	Clastic/salt interface						
	Clastic carbonate interface						
Prospect	Prospect definition						
	PSDM modelling						
	Prospect definition at relatively shallow depth (~<2km)						
	Sub basalt imaging		??				
	Sub Salt imaging						
	Lithology prediction						
	Fluid prediction						
Production and Reservoir Management	Production monitoring						
	PSDM modelling						
	Location of old wells and pipelines						
	Fault location						
	Fault mobility						
	Fracture orientation						
	Fracture location						

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	MT	CSEM	OBN
Cost $/stn deployment or well pad (*)		12,000-16,000				1,500-2,000		
Cost S/km		3,000 - 4,000	15-20	80	150	50	2,400	
Cost $/sq km								60,000-200,000
Basin	Tectonic basin formation mechanism							
	Crustal thickness							
	Heat flow history							
	Basin delineation							
	Depth to basement							
	Overthrust configuration							
	Basin fabric							
	Major fault delineation							
Play Fairway Analysis	Fault delineation							
	Cross section modelling						??	
	Detection/delineation of volcanics							
	Velocity constraints/modelling							
	PSDM modelling							
	Seismic migration improvement							
	Imaging prospect scale features							
	Clastic/salt interface							
	Clastic carbonate interface							
Prospect	Prospect definition							
	PSDM modelling							
	Prospect definition at relatively shallow depth (~<2km)							
	Sub basalt imaging		??					
	Sub Salt imaging							
	Lithology prediction							
	Fluid prediction							
Production and Reservoir Management	Production monitoring							
	PSDM modelling							
	Location of old wells and pipelines							
	Fault location							
	Fault mobility							
	Fracture orientation							
	Fracture location							

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	MT	CSEM	OBN	Microseis (*)
Cost $/stn deployment or well pad (*)		12,000-16,000				1,500-2,000			400,000-800,000
Cost S/km		3,000 - 4,000	15-20	80	150	50	2,400		300,000
Cost $/sq km								60,000-200,000	
Basin	Tectonic basin formation mechanism								
	Crustal thickness								Earthquakes
	Heat flow history								
	Basin delineation								
	Depth to basement								Earthquake/noise
	Overthrust configuration								
	Basin fabric								
	Major fault delineation								If faults active
Play Fairway Analysis	Fault delineation								If faults active
	Cross section modelling						??		
	Detection/delineation of volcanics								
	Velocity constraints/modelling								
	PSDM modelling								
	Seismic migration improvement								
	Imaging prospect scale features								
	Clastic/salt interface								
	Clastic carbonate interface								
Prospect	Prospect definition								
	PSDM modelling								
	Prospect definition at relatively shallow depth (~<2km)								
	Sub basalt imaging		??						
	Sub Salt imaging								
	Lithology prediction								
	Fluid prediction								
Production and Reservoir Management	Production monitoring								Pressure
	PSDM modelling								
	Location of old wells and pipelines								
	Fault location								
	Fault mobility								
	Fracture orientation								
	Fracture location								

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	MT	CSEM	OBN	Microseis (*)	Land 2D Seismic	Marine 2D Seismic	La Se
Cost $/stn deployment or well pad (*)		12,000-16,000				1,500-2,000			400,000-800,000			
Cost S/km		3,000 - 4,000	15-20	80	150	50	2,400		300,000	4,000-20,000	1,000-2,000	
Cost $/sq km								60,000-200,000				15 10
Basin	Tectonic basin formation mechanism											
	Crustal thickness								Earthquakes			
	Heat flow history											
	Basin delineation											
	Depth to basement								Earthquake/noise		Long offset	
	Overthrust configuration											
	Basin fabric											
	Major fault delineation								If faults active			
Play Fairway Analysis	Fault delineation								If faults active			
	Cross section modelling						??					
	Detection/delineation of volcanics											
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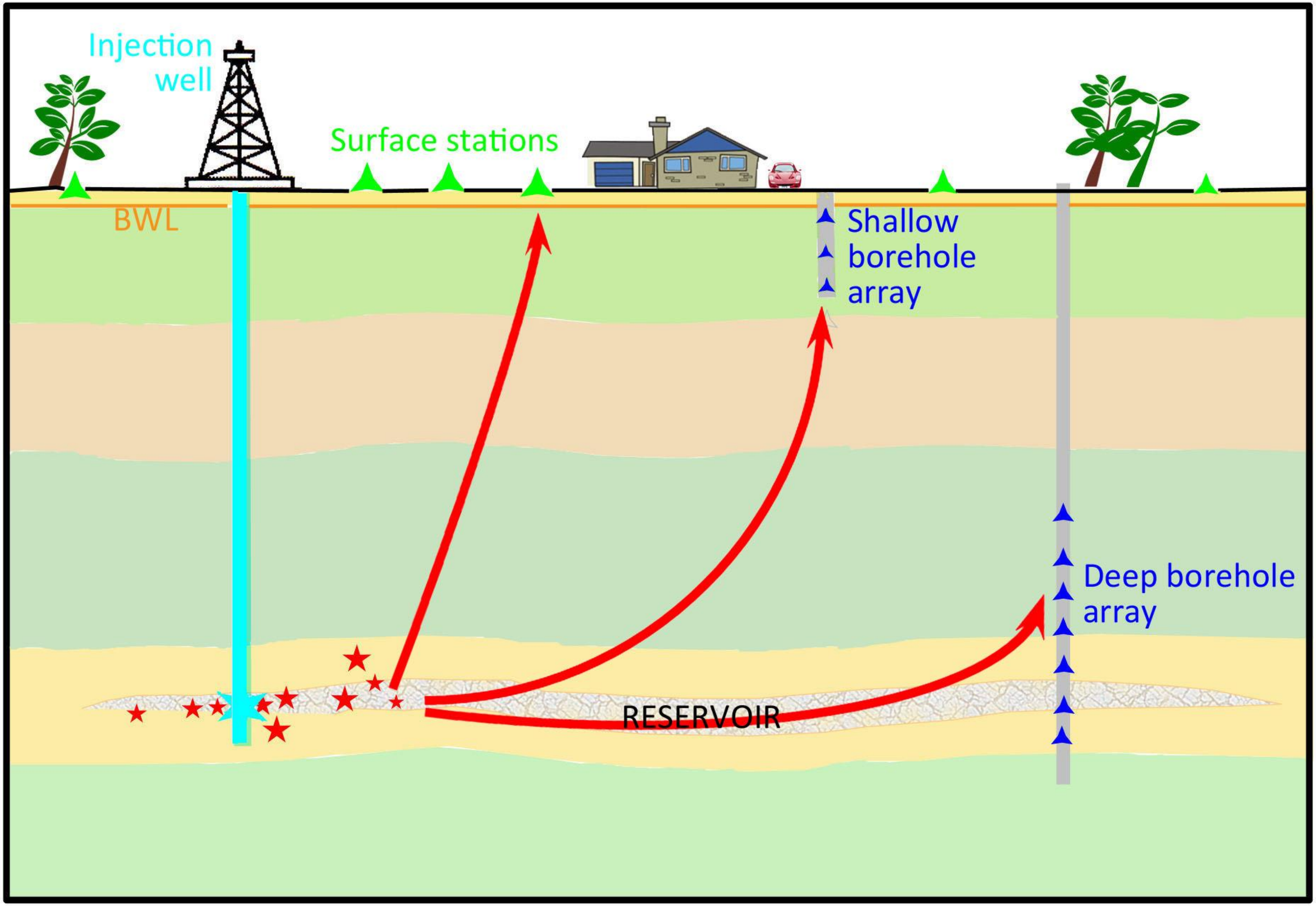
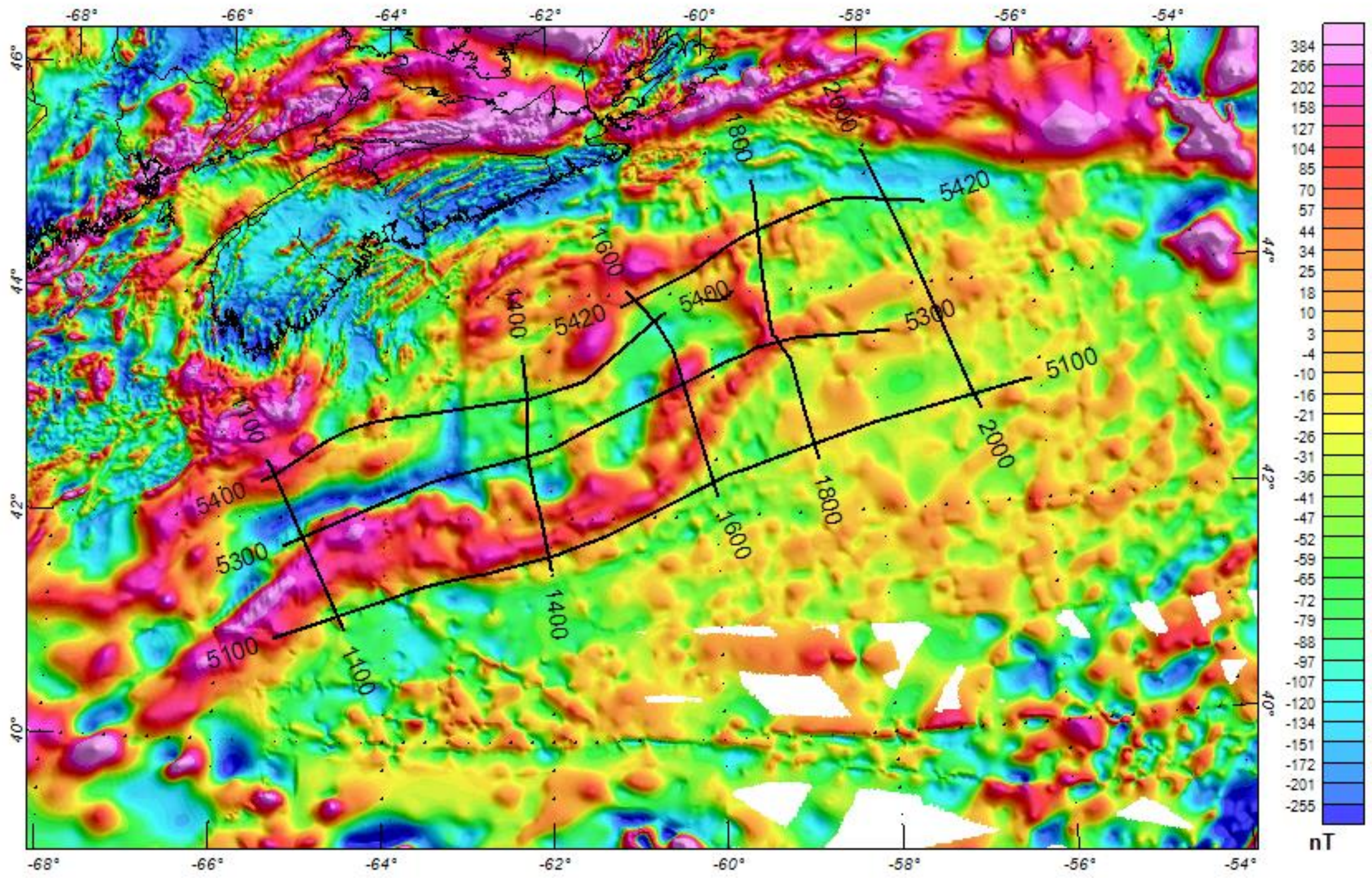
	Sub basalt imaging		??									
	Sub Salt imaging											
	Lithology prediction											
	Fluid prediction											
Production and Reservoir Management	Production monitoring								Pressure			
	PSDM modelling											
	Location of old wells and pipelines											
	Fault location											
	Fault mobility											
	Fracture orientation											
	Fracture location											

Where in the exploration cycle should we use these technologies

E&P phase							
	Basin Screening	**Access**	**Exploration**	**Prospect Identification**	**Appraisal**	**Development**	**Production**
Crustal geophysics							
Gravity & magnetics							
Full Tensor Gravity							**Untested**
CSEM							
Ocean Bottom Seismic							
Micro-seismic & passive seismic							


Injection well
Surface stations
BWL
Shallow borehole array
Deep borehole array
RESERVOIR

GXT NovaSpan Lines & SDR observations



OETR OBS survey – Velocity model

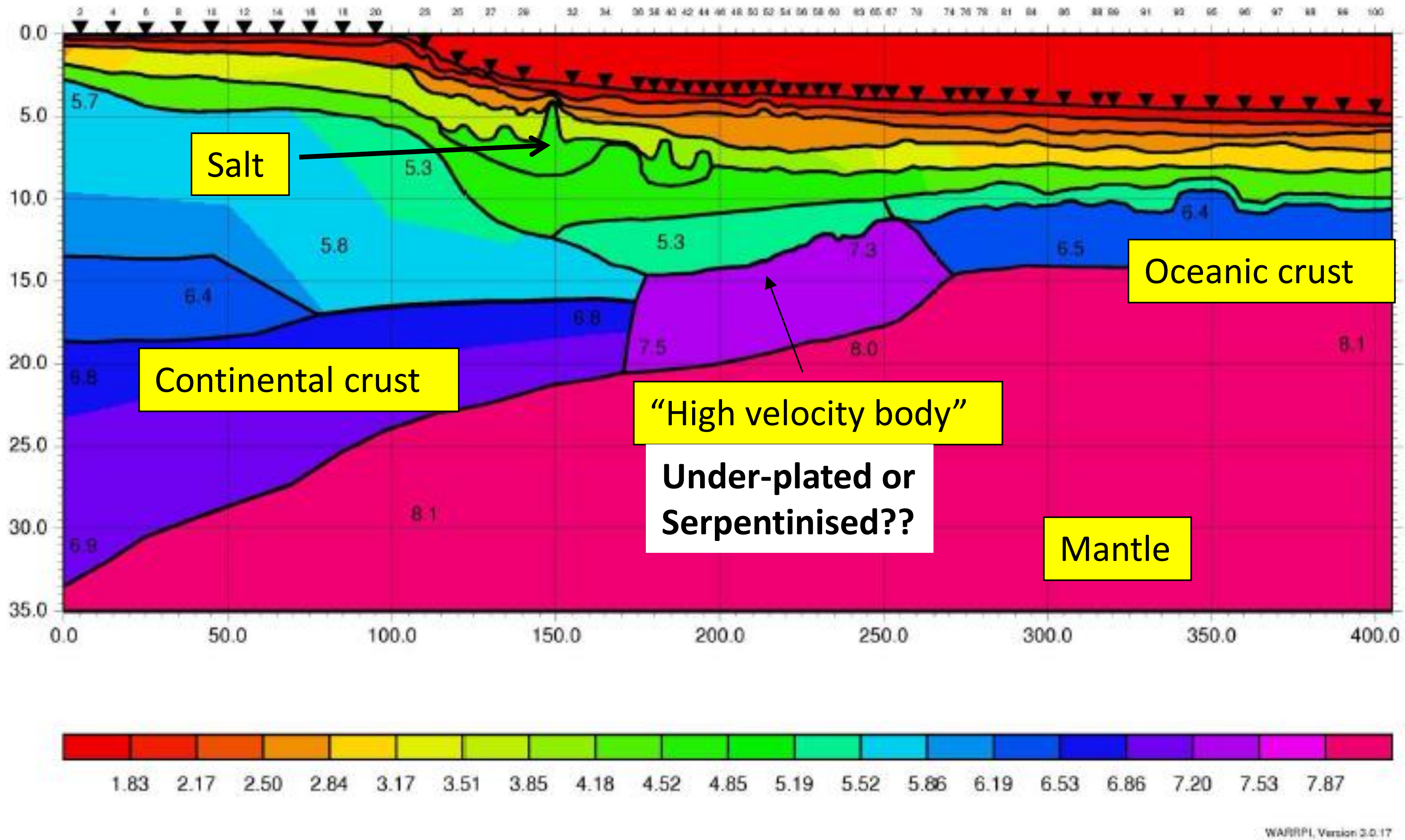
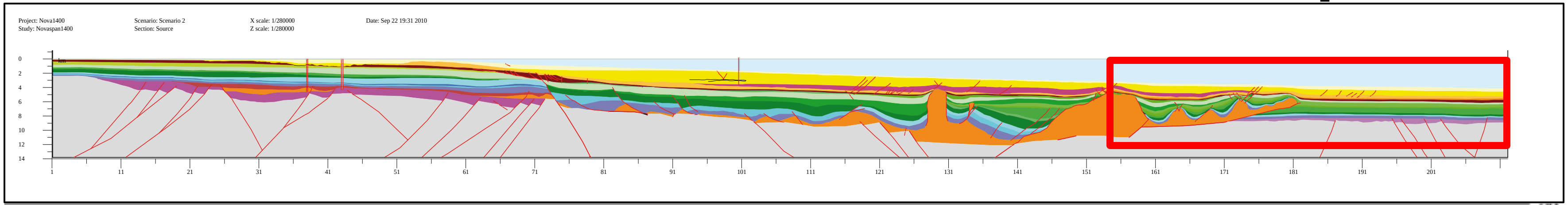
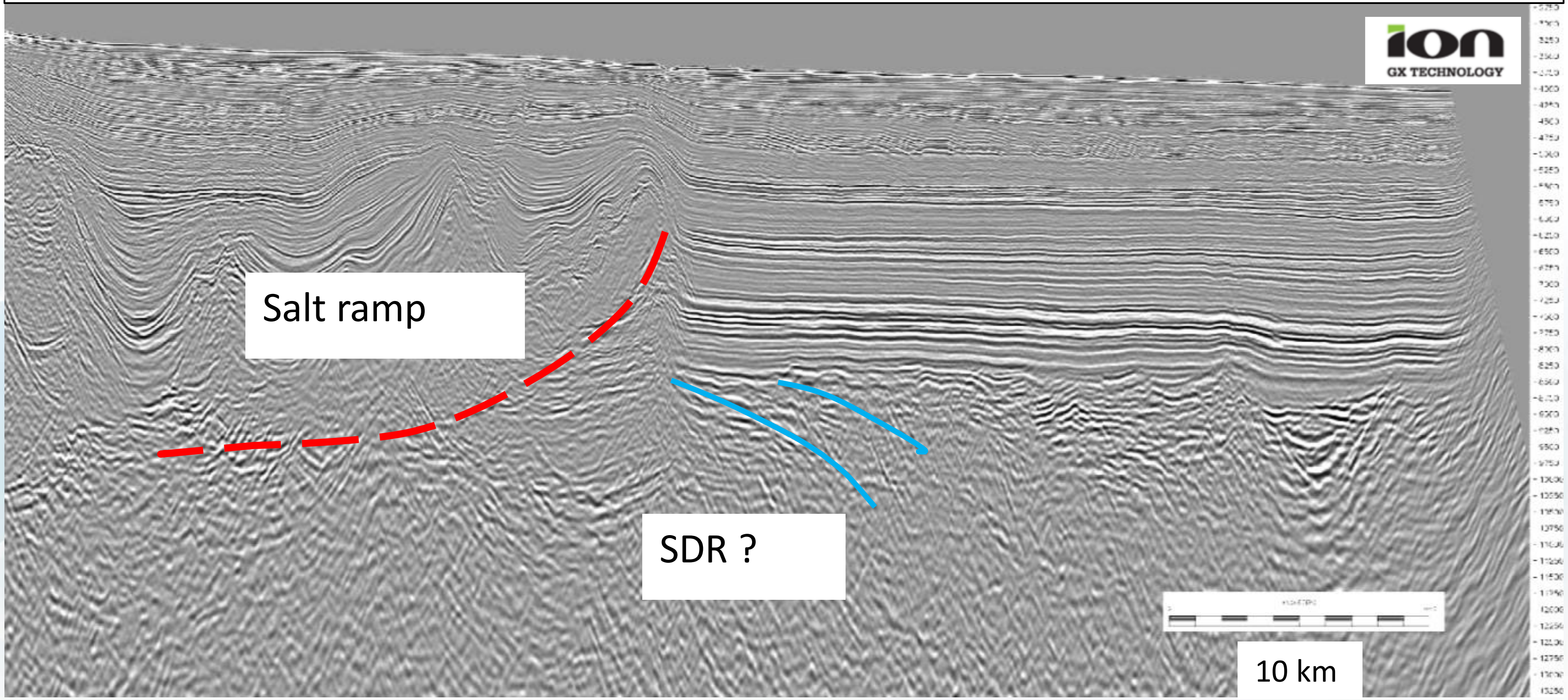


Figure 26. Final velocity model Nova Scotia 2009.

Line NovaSPAN 1400 Depth

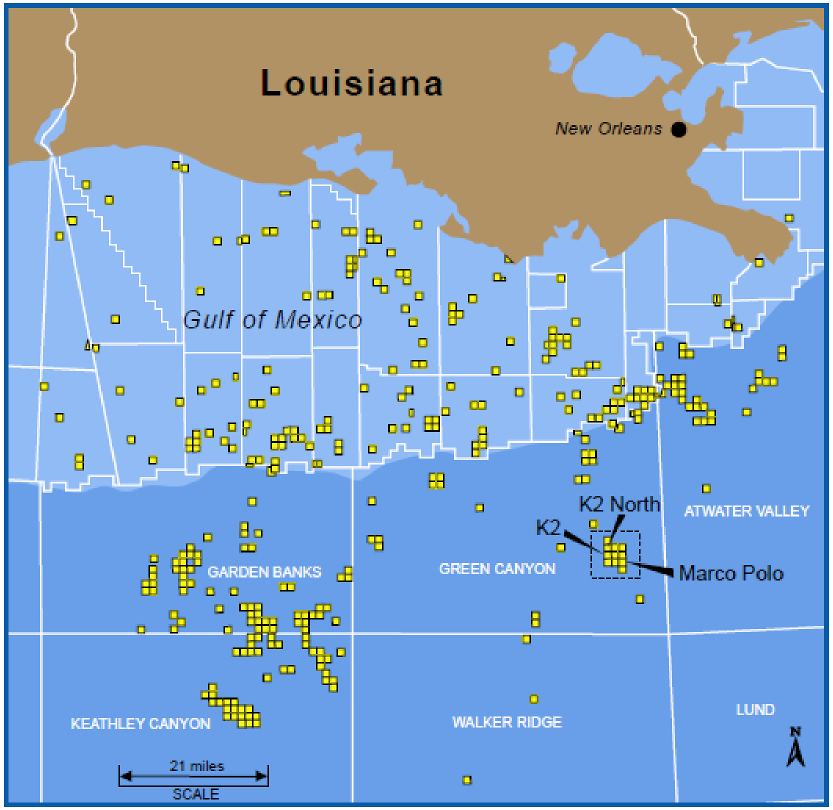


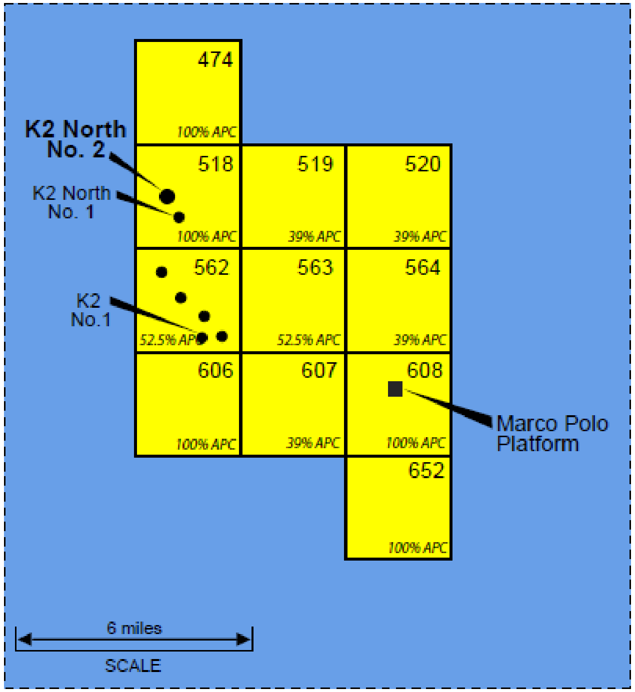


global environmental solutions

Anadarko Petroleum Corporation

Anadarko Expands Gulf of Mexico Discovery



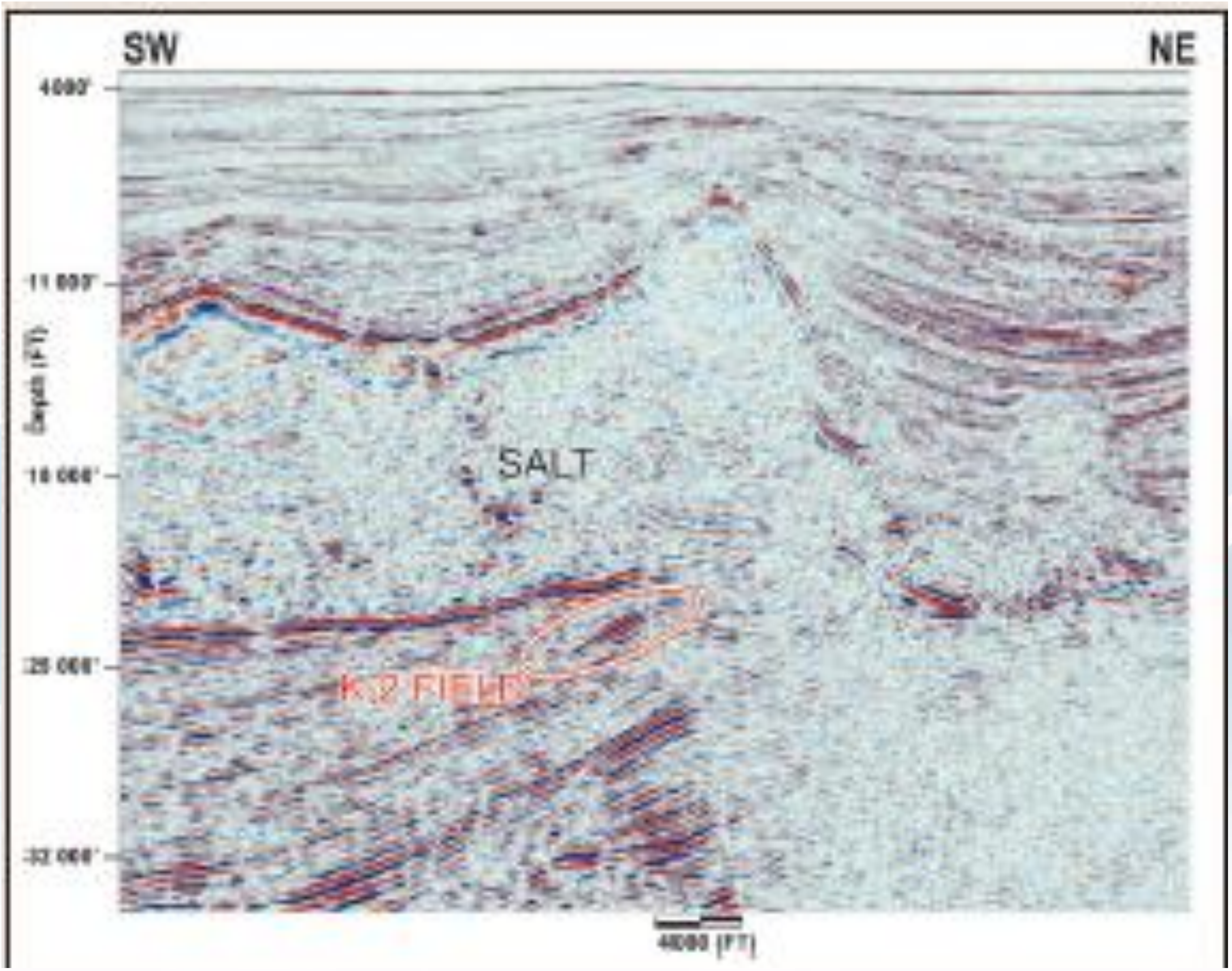


Anadarko Acreage

May 2004

A classic integrated application of potential field and seismic data is provided by the example of the appraisal of the K2 field

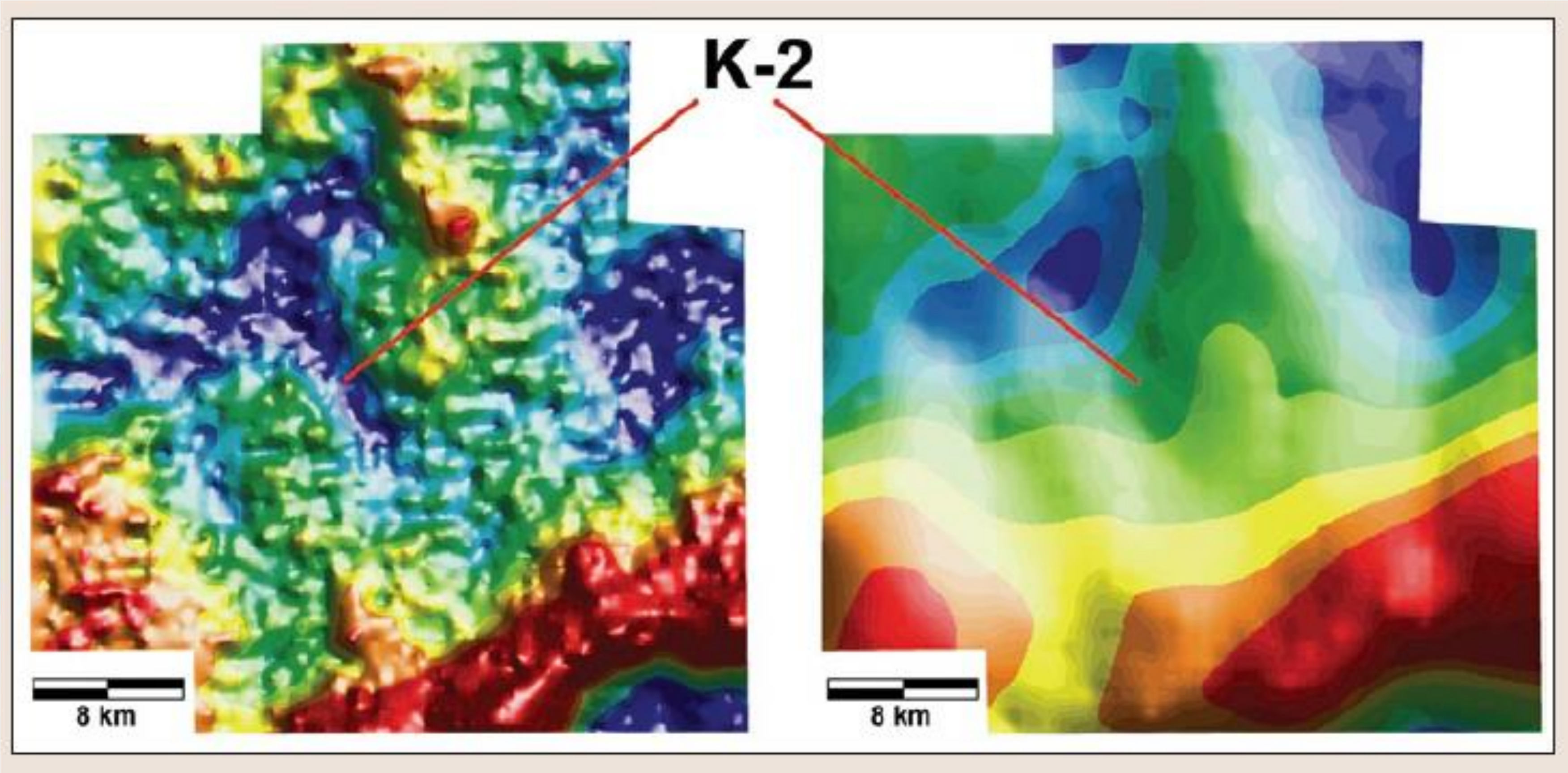
Where is the updip limit of the field?



Appraisal of the reservoir was faced with a very significant uncertainty in the extent of the sands up dip beneath a thick salt structure.

Gzz component of the gravity gradient field over K-2

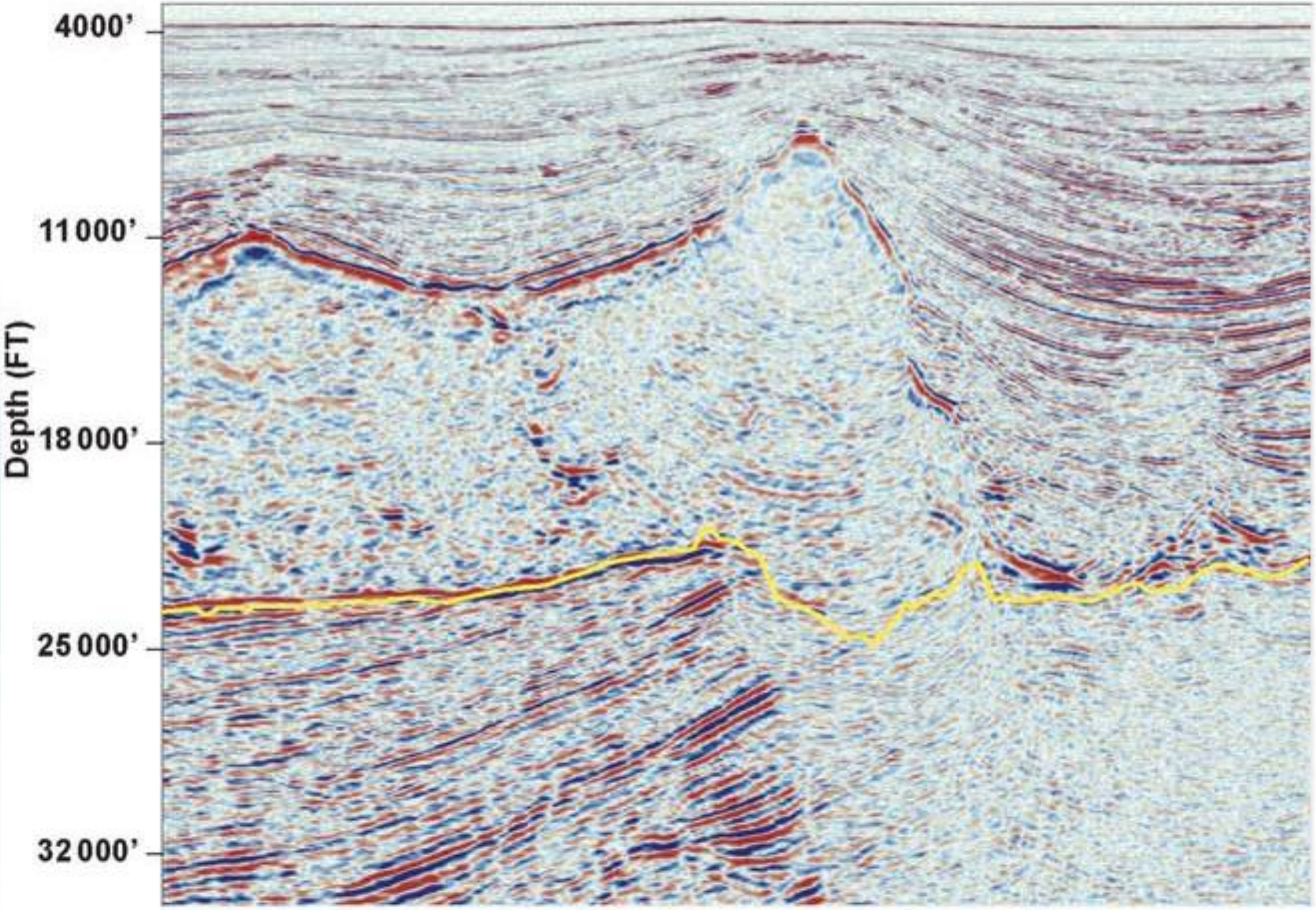
Conventional 3D free air gravity over the same area



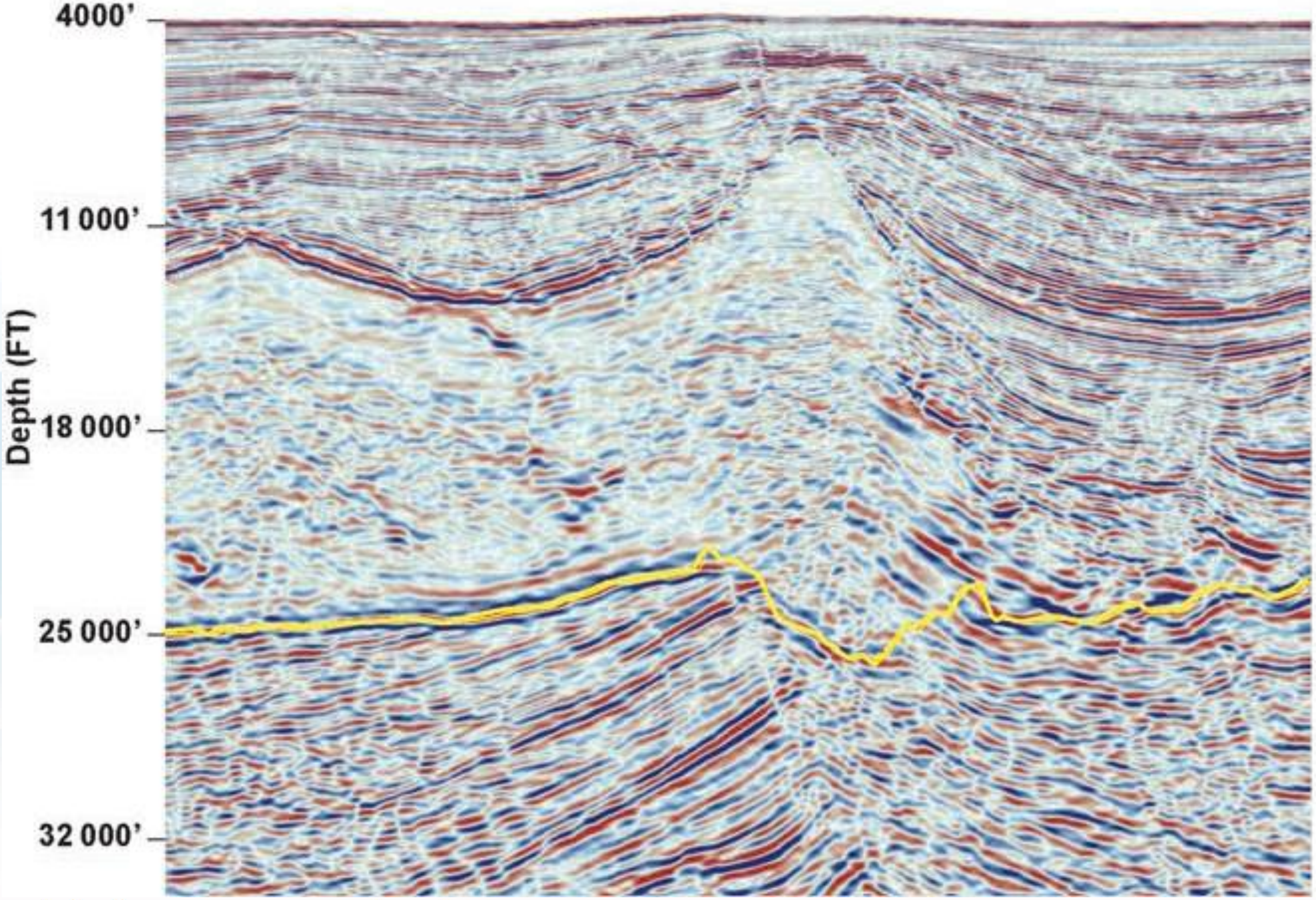
global environmental solutions

SLR

Gradiometry modeled base salt



Revised remigration



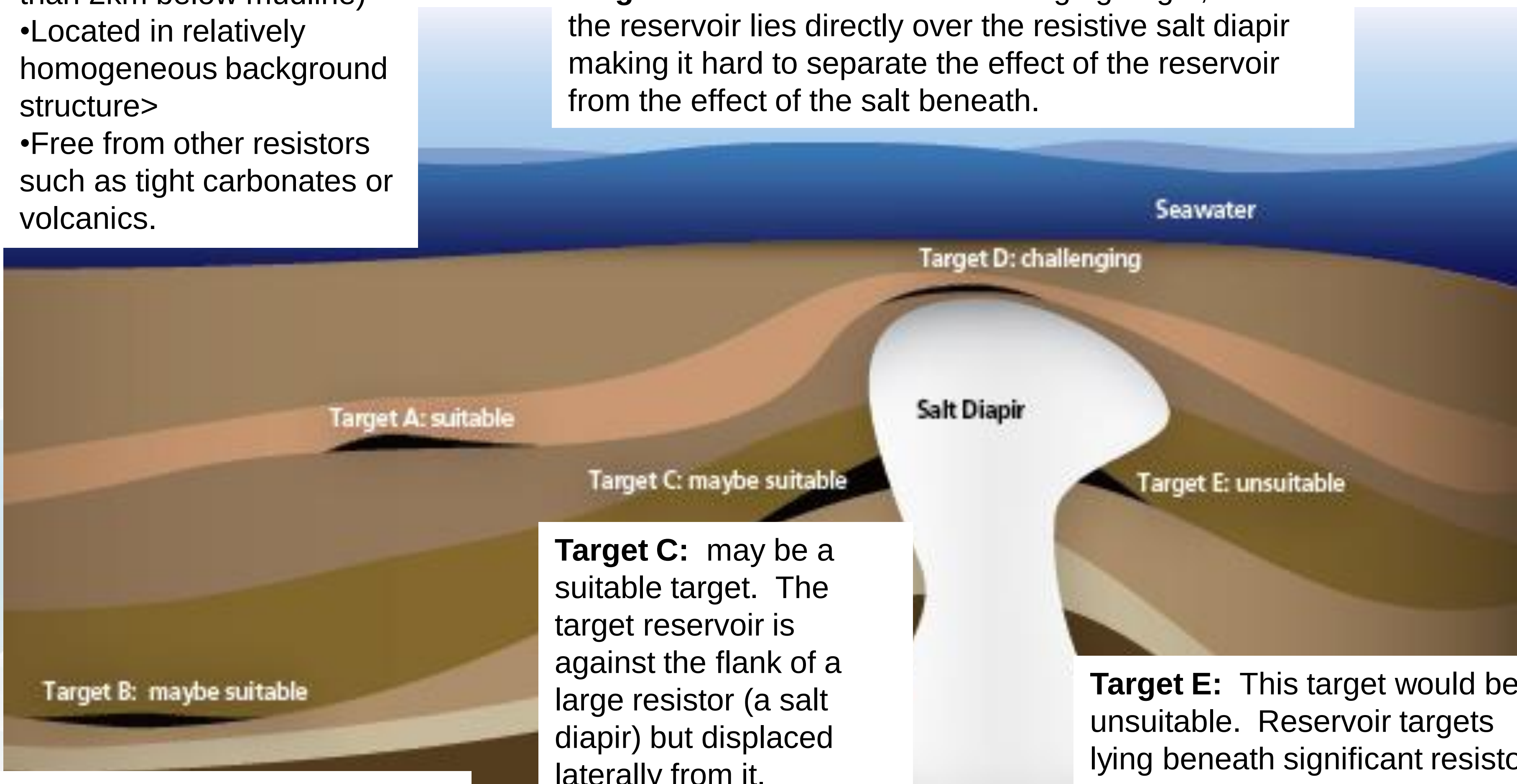
global environmental solutions

SLR

CSEM

Target A: A good target.
•It is relatively shallow in the section (perhaps less than 2km below mudline)
•Located in relatively homogeneous background structure>
•Free from other resistors such as tight carbonates or volcanics.

Target D: This would be a challenging target, because the reservoir lies directly over the resistive salt diapir making it hard to separate the effect of the reservoir from the effect of the salt beneath.

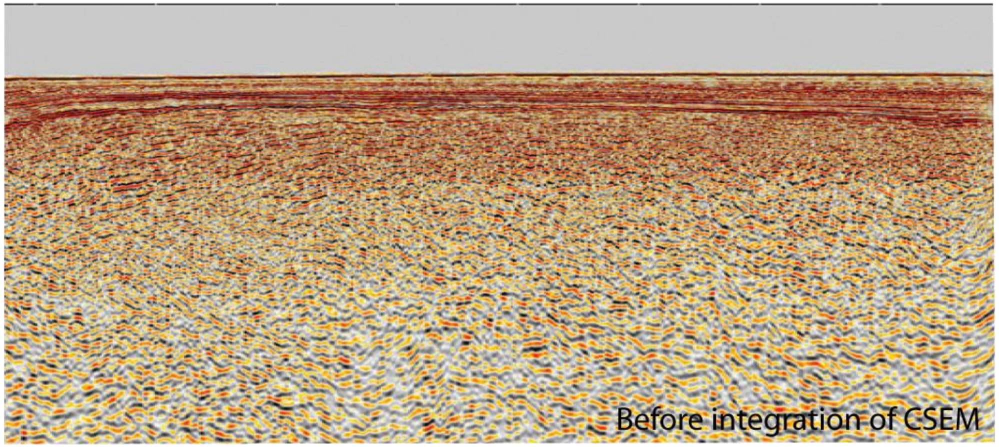


Target C: may be a suitable target. The target reservoir is against the flank of a large resistor (a salt diapir) but displaced laterally from it.

Target B: Maybe a suitable target. It is more challenging than target A, because it is deeper in the section, and closer to resistive basement beneath.

Target E: This target would be unsuitable. Reservoir targets lying beneath significant resistors such as salt, basalt or thick resistive carbonate sequences would not be resolved using the CSEM method

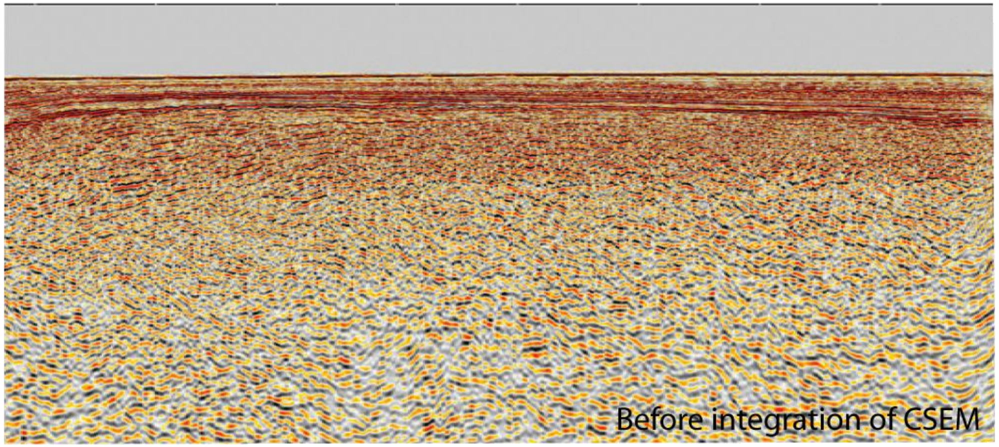
tions

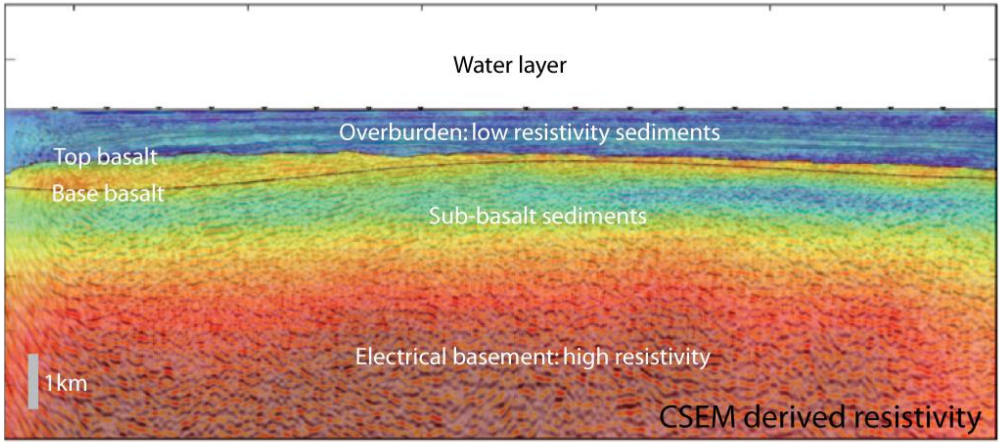


An example of seismic image improvement with CSEM

Little can be discerned beneath the top basalt boundary.

An example of seismic image improvement with CSEM

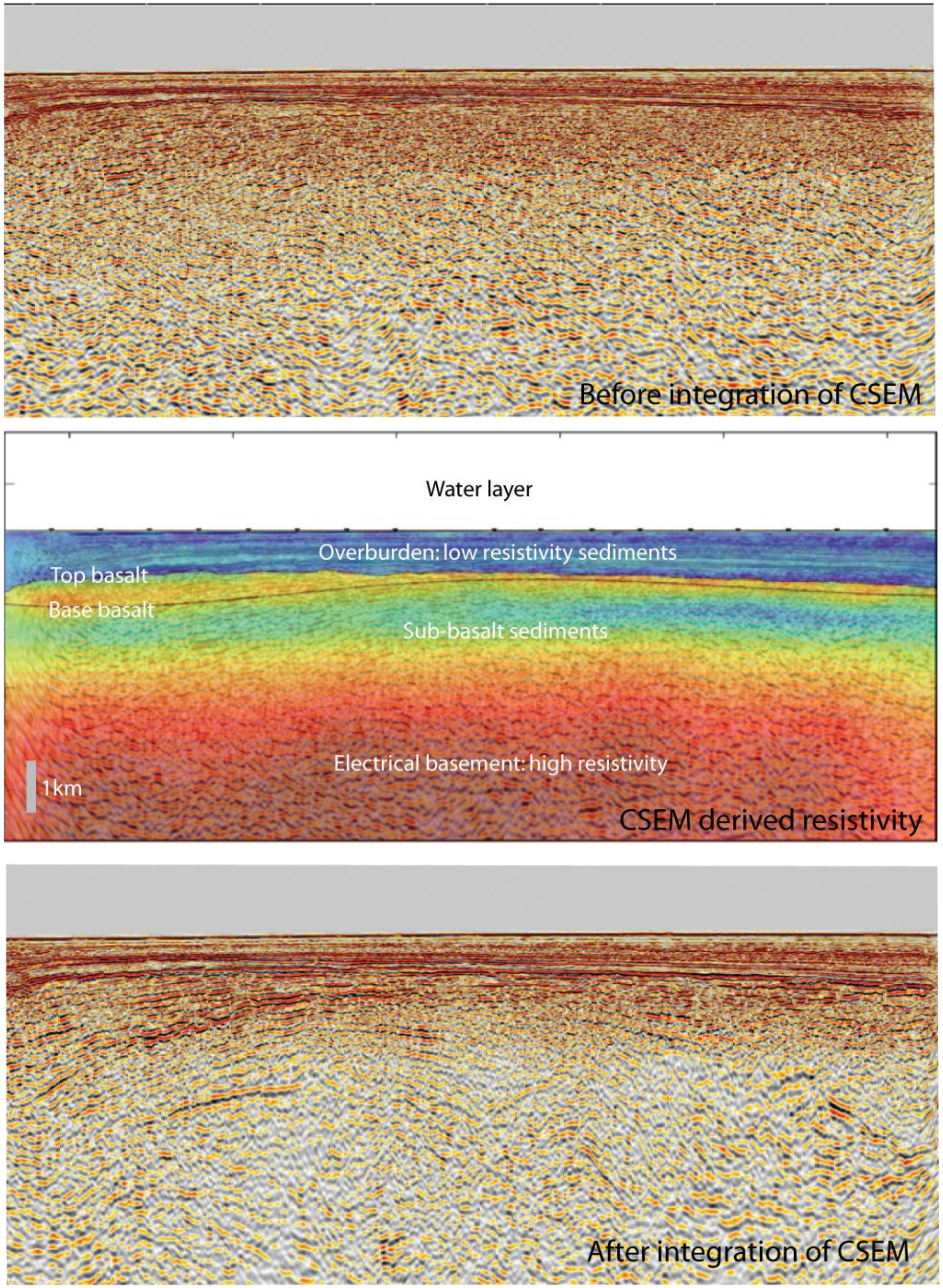




Little can be discerned beneath the top basalt boundary.

Yellow-red colours indicate high resistivity. The thin black line delineates a base basalt boundary picked from the resistivity data.

An example of seismic image improvement with CSEM



Little can be discerned beneath the top basalt boundary.

Yellow-red colours indicate high resistivity. The thin black line delineates a base basalt boundary picked from the resistivity data.

EM-derived information on basalt thickness merged with the velocity model. Sub-basalt structure is now much more successfully imaged

Final thoughts

- Know what you are looking for
- Every example of best practice will include:
  - Combinations of technologies
  - Calibration of seismic
- Integration