

A Review of Specialist Geoscience Technologies

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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
 - Gravity and magnetics
 - Gravity Gradiometry
 - Marine Electromagnetic methods
 - Ocean Bottom Marine Seismic Techniques Ian Jack
 - Micro Seismic

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Matt Luheshi

Lucy McGregor

Sue Raikes



Rock Measurements

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

Movement

Resistivity contrast

Obvious comments

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



FAILED RIFT SETTING

Offshore

Onshore



OFFSHORE PASSIVE MARGIN SETTING





Cost \$ /stn deployr	Geoscience Problem
Cost S/km	
Cost \$/sq km	
	Tectonic basin formation mechanism
	Crustal thickness
	Heat flow history
Basin	Basin delineation
	Depth to basement
	Overthrust configuration
	Basin fabric
	Major fault
	Fault delineation
	Cross section
	modering
.s	Detection/delineatio n of volcanics
lalys	Velocity
ıy Ar	constraints/modelli ng
airwa	PSDM modelling
ay Fa	Seismic migration
Pla	Imaging prospect
	scale features
	interface
	Clastic carbonate interface
	Prospect definition
	PSDM modelling
	Prospect definition
g	depth (~<2km)
osbe	
2 L	Sub basalt imaging
	Sub Salt imaging
	Lithology prediction
	Fluid prediction
nent	Production
agen	monitoring
Manë	PSDM modelling
voir	Location of old wells
esen	and pipelines
nd Re	Fault location
on al	Fault mobility
lucti	Fracture orientation
200	Fracture location

e technologies?

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

	Geoscience Problem	Land 2D	rine 2D	Land 3D	Marille 3D	
Cost \$/stn deployment	or	Seismic	Seismic	Seismic	Seismic	
Cost S/km		4,000- 20.000	1,000-2,000			
Cost \$/sq km 🛛 🧲				15,000- 100,000	8,000 - 30,000	\leq
	Tectori Jasin for traism					
	Crustal thickness					
_	Heat flow history					
y Analysis Basir	Basin delineation					
	Depth to basement		Long offset			
	Overthrust configuration					
	Basin fabric					
	Major fault delineation					
	Cross section modelling					
	Detection/delineation of volcanics					
	Velocity constraints/modelling					
irwa	PSDM modelling					
ay Fai	Seismic migration improvement					
ä	Imaging prospect scale features					
	Clastic/salt interface Clastic carbonate					
	interface					
	Prospect definition					
ect	PSDM modelling Prospect definition at relatively shallow depth (~<2km)					
Prosp	Sub basalt imaging					
	Sub Salt imaging					
	Lithology prediction					
	Fluid prediction					
voir	Production monitoring					
ser	PSDM modelling					
ind Re lemen	Location of old wells and pipelines					
on a inag	Fault location					
ucti ⁱ Ma	Fault mobility					
Prod	Fracture orientation					
L	Eracture location					

Consider these costs – particularly on shore

	Geoscience	Crustal Seismic
Cost \$/stn deploy (*)	ment or well pad	12,000-
Cost S/km		3,000 - 4.000
Cost \$/sq km		.,
	Tectonic basin formation mechanism	
Cost \$/stn deploy Cost \$/km Cost \$/km Cost \$/sq km Basin Basin Basin Basin Basin	Crustal thickness	
	Heat flow history	
sin	Basin delineation	
Ba	Depth to	
	Overthrust	
Play Fairway Analysis	configuration	
	Basin fabric	
	Major fault	
	Fault delineation	
	Cross section	
	modelling	
Production and Reservoir Management Management	Detection / deline	
	ation of volcanics	
	Velocity	
	constraints/mode lling	
	PSDM modelling	
	Seismic migration	
	improvement	
	Imaging prospect scale features	
	Clastic/salt interface	
	Clastic carbonate	
	Prospect	
Prospect Play Fairway Analysis	definition	
	PSDM modelling	
	definition at	
ect	relatively shallow	
dsa	aepth (~<2KM) Sub basa!+	
Pré	imaging	
	Sub Salt imaging	
	Lithology	
	prediction	
	Fluid prediction	
ir	Production monitoring	
irve	PSDM modelling	
nt	Location of old	
a R B	wells and	
an		
ang	Fault location	
Σ ^t t	Fault mobility	
rod	Fracture	
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	Geoscience Problem	Crustal Seismic	AeroMagne tics
Cost \$/stn deploymen	12,000- 16,000		
Cost S/km		3,000 - 4,000	15-20
Cost \$/sq km			
	Tectonic basin formation mechanism		
	Crustal thickness		
	Heat flow history		
sin	Basin delineation		
Ba	Depth to basement		
8 8	Overthrust configuration		
	Basin fabric		
ost \$/stn deploymer ost S/km ost \$/sq km st \$/sq km Basin Play Fairway Analysis Basin Play Fairway Analysis	Major fault delineation		
	Fault delineation		
irway Analysis	Cross section modelling		
	Detection/delineation of volcanics		
	Velocity constraints/modellin g		
	PSDM modelling		
ay Fai	Seismic migration improvement		
ä	Imaging prospect scale features		
	Clastic/salt interface		
	Clastic carbonate interface		
	Prospect definition		
bect	PSDM modelling Prospect definition at relatively shallow depth (~<2km)		
Production and Reservoir Prospect Play Fairway Analysis Management Management	Sub basalt imaging		77
•	Sub Salt imaging		
Production and Reservoir Management Prospect Play Fairway Analysis Basin Prospect	Lithology prediction		
	Fluid prediction		
oir	Production monitoring		
Ser	PSDM modelling		
nd Re ement	Location of old wells and pipelines		
ion ar anag(Fault location		
Δ	Fault mobility		
Prod	Fracture orientation		
	Fracture location		

	Geoscience Problem	Crustal Seismic	AeroMagneti cs	AeroGravity
ost \$/stn deployment o	or well pad (*)	12,000- 16,000		
ost S/km		3,000 - 4,000	15-20	80
ost \$/sq km		• • • •		
	Tectonic basin formation mechanism			
	Crustal thickness			
	Heat flow history			
<u>s</u> i.	Basin delineation			
Ba	Depth to basement			
	Overthrust configuration			
	Basin fabric			
	Major fault delineation			
	Fault delineation			
	Cross section modelling			
Analysis	Detection/delineation of volcanics			
	Velocity constraints/modelling			
way	PSDM modelling			
/ Fairv	Seismic migration improvement			
Plan	Imaging prospect scale features			
Play Fai	Clastic/salt interface			
	Clastic carbonate interface			
	Prospect definition			
ect	PSDM modelling Prospect definition at relatively shallow depth (~<2km)			
Prosp	Sub basalt imaging		22	
—	Sub Salt imaging			
	Lithology prediction			
	Fluid prediction			
÷	Production monitoring			
ervo	PSDM modelling			
d Rese nent	Location of old wells and pipelines			
on anc nager	Fault location			
Mai	Fault mobility			
rodt	Fracture orientation			
٩	Fracture location			

	Geoscience Problem	Crustal Seismic	AeroMagnetic s	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					
	Tectonic basin formation mechanism				
	Crustal thickness				
	Heat flow history				
sin	Basin delineation				
Ba	Depth to basement				
	Overthrust configuration				
	Basin fabric				
	Major fault delineation				
	Fault delineation				
	Cross section modelling				
Analysis	Detection/delineation of volcanics				
	Velocity constraints/modelling				
vay	PSDM modelling				
Fairw	Seismic migration				
Play	Imaging prospect scale features				
	Clastic/salt interface				
	Clastic carbonate				
	Prospect definition				
t	PSDM modelling Prospect definition at relatively shallow depth				
ê S					
۲. C	Sub basalt imaging		22		
	Sub Salt imaging				
	Lithology prediction				
	Fluid prediction				
. 	Production monitoring				
IVO	PSDM modelling				
Rese	Location of old wells and pipelines				
n and nagen	Fault location				
Mai	Fault mobility				
Produ	Fracture orientation				
—	Fracture location				

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	МТ
Cost \$/stn deployment	t 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						
	Tectonic basin formation mechanism					
	Crustal thickness					
_	Heat flow history					
asin	Basin delineation					
Ä	Depth to basement					
	Overthrust configuration					
	Basin fabric					
	Major fault delineation					
	Fault delineation					
	Cross section modelling					
.s	Detection/delineation of volcanics					
/ay Analy	Velocity constraints/modelling					2
	PSDM modelling					
Fairv	Seismic migration improvement					
Play	Imaging prospect scale features					
	Clastic/salt interface					
	Clastic carbonate interface					
	Prospect definition					
	PSDM modelling Prospect definition at					
pect	relatively shallow depth (~<2km)					
Pros	Sub basalt imaging		??			
_	Sub Salt imaging					
	Lithology prediction					
	Fluid prediction					
L .	Production monitoring					
voi	PSDM modelling					
Reser	Location of old wells and pipelines					
and	Fault location					
uction Manë	Fault mobility					
Produ	Fracture orientation					
-	Fracture location					

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	мт	CSEM
ost \$/stn deployment or w	vell pad (*)	12,000-16,000				1,500-2,000	
ost S/km		3,000 - 4,000	15-20	80	150	50	2,400
ost \$/sq km							·
	Tectonic basin formation mechanism						
	Crustal thickness						
	Heat flow history						
lasin	Basin delineation						
Ξ.	Depth to basement						
	Overthrust configuration						
	Basin fabric						
	Major fault delineation						
	Fault delineation						
	Cross section modelling						77
.s	Detection/delineation of volcanics						
ay Analy:	Velocity constraints/modelling						
	PSDM modelling						
Fairv	Seismic migration						
Play	Imaging prospect scale features						
	Clastic/salt interface						
	Clastic carbonate interface						
	Prospect definition						
	PSDM modelling						
ect	Prospect definition at relatively shallow depth (~<2km)						
losp	Sub basalt imaging		??				
E	Sub Salt imaging						
	Lithology prediction						
	Fluid prediction						
	Production monitoring						
voir	PSDM modelling						
Reser	Location of old wells and pipelines						
and Jgem	Fault location						
Manë	Fault mobility						
npou	Fracture orientation						
E	Fracture location						

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	МТ	CSEM	OBN
ost \$/stn deployment or we	ell pad (*)	12,000-16,000				1,500-2,000		
ost S/km		3,000 - 4,000	15-20	80	150	50	2,400	
Cost \$/sq km								60,000- 200,000
	Tectonic basin formation mechanism							
	Crustal thickness							
	Heat flow history							
asin	Basin delineation							
æ	Depth to basement							
	Overthrust configuration							
	Basin fabric							
	Major fault delineation							
	Fault delineation							
	Cross section modelling						22	
Analysis	Detection/delineation of volcanics							
	Velocity constraints/modelling							
vay	PSDM modelling							
Fairv	Seismic migration							
Play	Imaging prospect scale features							
	Clastic/salt interface							
	Clastic carbonate interface							
	Prospect definition							
	PSDM modelling							
ect	Prospect definition at relatively shallow depth (~<2km)							
Prosp	Sub basalt imaging		22					
L	Sub Salt imaging							
	Lithology prediction							
	Fluid prediction							
L	Production monitoring							
voi	PSDM modelling							
Reser	Location of old wells and pipelines							
agem	Fault location							
Man	Fault mobility							
rodu	Fracture orientation							
E	Fracture location							

	Geoscience Problem	Crustal Seismic	AeroMagnetics	AeroGravity	FTG	мт	CSEM	OBN	Microseis (*)
ost \$/stn deployment or we	ell pad (*)	12,000-16,000				1,500-2,000			400,000- 800,000
ost S/km		3,000 - 4,000	15-20	80	150	50	2,400		300,000
ost \$/sq km	r							60,000- 200,000	
	Tectonic basin formation mechanism								
	Crustal thickness								Earthquakes
asin	Heat flow history								
	Basin delineation								
ш	Depth to basement								Earthquake/noise
	Overthrust configuration								
	Basin fabric								
	Major fault delineation								If faults active
	Fault delineation								If faults active
	Cross section modelling						<u>n</u>		
sis	Detection/delineation of volcanics								
Analys	Velocity constraints/modelling								
/a/	PSDM modelling								
Fairw	Seismic migration improvement								
Play	Imaging prospect scale features								
	Clastic/salt interface								
	Clastic carbonate interface								
	Prospect definition								
	PSDM modelling								
et	Prospect definition at relatively shallow depth (~<2km)								
rosp	Sub basalt imaging		77						
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	Lithology prediction								
	Fluid prediction								
	Production monitoring								Pressure
voir	PSDM modelling								
Reser	Location of old wells and pipelines								
n and nagem	Fault location								
Mar	Fault mobility								
Produ	Fracture orientation								
٩	Fracture location								

	Geoscience Problem	Crustal Seismic	AeroMagneti cs	AeroGravity	FTG	мт	CSEM	OBN	Microseis (*)	Land 2D Seismic	Marine 2D Seismic	La
Cost \$/stn deployment	or well pad (*)	12,000- 16,000				1,500-2,000			400,000- 800,000			Se
Cost S/km		3,000 -	15.00		450	50	2 400		200,000	4,000-	1 000 0 000	
Cost \$ /sa km		4,000	15-20	80	150	50	2,400	60,000-	300,000	20,000	1,000-2,000	1!
505t \$/54 km	Testenis kesin							200,000				10
	formation mechanism											
	Crustal thickness								Earthquakes			<u> </u>
	Heat flow history											
Basin	Basin delineation											
	Depth to basement Overthrust configuration								Earthquake/noise		Long offset	
	Basin fabric											
	Major fault delineation								If faults active			
	Fault delineation								If faults active			
si Det si Oet si of v le Velo e Con	Cross section modelling											
	Detection/delineation of volcanics											
	Velocity constraints/modelling											
/ay	PSDM modelling											
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	Clastic/salt interface Clastic carbonate											
	Interface Prospect definition											
	Prospect definition											
bect	Prospect definition at relatively shallow depth (~<2km)											
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ď	Sub Salt imaging											
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Rese	Location of old wells											
and gem	Eault location											
on é												
Ma	Fault mobility											
rodu	Fracture orientation											
Ā	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							



GXT NovaSpan Lines & SDR observations



OETR OBS survey – Velocity model



WARRPI, Version 3.0.17



Line NovaSPAN 1400 Depth







Anadarko Expands Gulf of Mexico Discovery



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





Gradiometry modeled base salt



SLR

Revised remigration





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.

CSEM

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.

Seawater

resistive carbonate sequences

would not be resolved using the

CSEM method



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



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

