CSEM Ranking of Transform Margin Prospects*

Friedrich Roth¹, Lodve Berre¹, Stein Fanavoll¹, and Charles Thomas¹

Search and Discovery Article 11182 (2019)**
Posted January 14, 2019

*Adapted from oral presentation given at 2018 International Conference and Exhibition, Cape Town, South Africa, November 4-7, 2018
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¹EMGS, Trondheim, Norway (lb@emgs.com)

Abstract

The Transform Margin play is a prolific HC play explored along the equatorial margins of Africa and South America. Significant discoveries include Jubilee (Ghana) and Liza (Guyana). The play consists of Late Cretaceous deep-water slope and basin floor channels and fans with structural/stratigraphic trapping. While prospects are typically well mapped with seismic and commonly exhibit seismic DHI’s, their stratigraphic nature implies high risk and commercial drilling success rate has been declining recently, e.g. Fatala (Guinea). The highest risks typically are seal integrity and charge. De-risking with seismic DHI’s is notoriously difficult due to the strong response from low saturation HC. As exemplified by the successful CSEM track record in Norway for both structural and stratigraphic plays, integration of resistivity from CSEM with seismic can de-risk seal and charge by distinguishing high from low saturation HC. Moreover, CSEM can reduce uncertainty in the prospect resources. Hence CSEM is a very valuable tool for de-risking AVO and seismic amplitude driven prospects, particularly in deep water where only large volumes are commercial. Existing CSEM data at the West African equatorial margin dates from the early years of commercializing CSEM technology (2002-2007). While some of these data proved the capability of CSEM to de-risk stratigraphic prospects (e.g. Fortuna in Eq. Guinea), the legacy data mostly failed to be of value due to immature products: the lack of imaging and non-existence of workflows to embed CSEM in prospect evaluation. These early shortcomings have now been overcome by tremendous technological advances and experience building from worldwide CSEM application. To illustrate the ability of modern CSEM to increase exploration performance for the Transform Margin play, we studied a drilling commitment for a hypothetical portfolio of four prospects in deep water Guinea. The setting is an analog to the Fatala prospect with high resource potential but significant uncertainty. We model the impact of CSEM information on the PoS and volume distribution of each prospect. Due to excellent CSEM sensitivity to the Late Cretaceous, only small volumes are undetectable
and thus a prospect without a resistive anomaly has very low probability of commercial success \((P_c)\). We then simulate a drilling candidate selection and show that by downgrading prospects without a resistive anomaly the \(P_c\) of the first well is at least as high as drilling two wells without CSEM.

**References Cited**


CSEM Ranking of Transform Margin Prospects

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¹ EMGS, ² Presenter
Outline

• Problem: Lack of exploration success on the Atlantic Transform Margin
• Reason: Seal and charge failure
• Solution: CSEM provides information on seal and charge
• Norwegian CSEM track record
• CSEM experience in Africa to date
• Guinea Synthetic Exploration Example
Exploration Success Rate is LOW

Only 8% of 110 frontier wells in the Atlantic Margin was considered commercial (from 2007-2015)

Source: Richmond Energy Partners / Westwood Group

Global conventional discoveries** [Million boe]

- Liquids
- Gas
- Year average

Atlantic margin

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Volume per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>30 billion boe</td>
</tr>
<tr>
<td>2013</td>
<td>16 billion boe</td>
</tr>
<tr>
<td>2014</td>
<td>15 billion boe</td>
</tr>
<tr>
<td>2015</td>
<td>15 billion boe</td>
</tr>
<tr>
<td>2016</td>
<td>8 billion boe</td>
</tr>
<tr>
<td>2017</td>
<td>6.7 billion boe</td>
</tr>
</tbody>
</table>

Source: Rystad Energy UCube and Rystad Energy research and analysis

Source: Richmond Energy Partners / Westwood Group
Why Is The Success Rate Low?

Global well failure statistics

Source: Supermajor

73% dry

27%

165 global frontier wells:
45 discoveries
120 dry

75% of these were attributed to lack of seal or missing charge

Seal 45%
Charge 30%
Reservoir 15%
Trap 10%
Marine 3D CSEM In A Nutshell

Marine CSEM images formation resistivity remotely from the seabed

Active source (CSEM)
Horizontal electric dipole

Acquisition
20 – 3500m

Sensitivity
0-4000 m BML

Multi-component EM seabed receiver
Electric and magnetic field sensors
CSEM Sensitive to Seal & Charge

Source: Alcocer et al., 2013-04, First Break vol. 31
CSEM Sensitive to Seal & Charge

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Source: Constable, 2010, Geophysics
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Source: Constable, 2010, Geophysics
CSEM In Exploration Perspective

Risk = 1 - P_g

Area [km^2] x Net thickness [m] x Δ Resistivity [Ωm]

Sensitivity to the target
Low → High

P90
P50
P10

Risk = 1 - P_g
Prediction Strength – Norway

CSEM POSITIVE

CSEM NEGATIVE

Wisting

Hanssen

Mercury
Prediction Strength – Norway

CSEM POSITIVE
CSEM NEGATIVE

- Wisting
- Hanssen
- Mercury

CSEM positive: PoS 67%
Prior: PoS 20%

CSEM negative: PoS 8%
Prediction Strength – Norway

Source: OMV, Arctic Safety Summit 2018-03-21
CSEM Experience In Africa To Date

Legacy case study: Nigeria OPL322

First CSEM pilot: November 2000
CSEM Experience In Africa To Date

2006 Attribute Analysis

2006 attribute analysis correctly predicted discovery at crest of structure.

Source: Moser et al, The Leading Edge (2006-08) Pg. 977-982

2018 Unconstrained Inversion

2018 inversion identifies discovery at crest of structure and potential upside down-dip.

Well log: Good quality sands, 2-30m Rh

CSEM Courtesy of HARVEX
Portfolio Modelling Example

• 1 well drilling campaign
• Target: Upper Cretaceous turbidite fan play
• 4 prospect portfolio
• Volumes:
  • P10 & PMean from public information
  • P90 from Swanson’s rule
  • Lognormal volume distribution
• MEFS = 200 MMbbl
• PoS: 28% for all prospects
• Pe: 19% for Fatala
• CSEM false positive risk: 20%

Source: Hyperdynamics, Oil Capital Conference, London 2016-09-21
Portfolio Modelling Example

Portfolio Modelling Example

Portfolio Modelling Example

Old drilling rule based on seismic: Drill highest Pe

- Fatale: 19%
- Oasis: 19%
- Sylli: 13%
- Bamboo: 12%

Chance of Economic Success (Pe)
Portfolio Modelling Example

New drilling rule: Drill highest Pe from CSEM

Fatala: 46% Pe
Oasis: 46% Pe
Sylli: 33% Pe
Bamboo: 32% Pe

Pe with CSEM: 35%

Prior PMean
PMean if EM Pos
PMean if EM Neg
Portfolio Modelling Example

If Fatala is CSEM negative, Pe drops to 6% – drill Oasis instead.
Portfolio Modelling Example

If Oasis is CSEM negative, $Pe$ drops to 6% – drill Sylli instead.

```
Fatala          Oasis          Sylli          Bamboo

Pe with
CSEM: 35%

Chance of Economic Success (Pe)

50%  40%  30%  20%  10%  0%

Fatala: 15%  Oasis: 19%  Sylli: 33%  Bamboo: 32%

Fatala: 6%  Oasis: 6%  Sylli: 3%  Bamboo: 3%

Prior PMean

Pe if EM Pos

Pe if EM Neg
```
Portfolio Modelling Example

If Sylli is CSEM negative, Pe drops to 3% – drill Bamboo instead

Pe with CSEM: 35%

- Fatala: Prior PMean 15%, PMean if EM Pos 6%, PMean if EM Neg 6%
- Oasis: Prior PMean 1%, PMean if EM Pos 6%, PMean if EM Neg 6%
- Sylli: Prior PMean 1%, PMean if EM Pos 3%, PMean if EM Neg 3%
- Bamboo: Prior PMean 12%, PMean if EM Pos 32%, PMean if EM Neg 3%
Portfolio Modelling Example

If Bamboo is CSEM negative, Pe drops to 3% – drill Fatala instead...

Pe with CSEM: 35%
Strong sensitivity to the Upper Cretaceous interval makes the chance of an economic discovery essentially zero with a CSEM negative observation.

- **1 well commitment:**
  - CSEM increases probability of economic discovery (Pe) from 19% to 35% - as good as drilling 2 wells!
  - Expected value of the Upper Cretaceous portfolio doubled

- **2 well commitment:**
  - CSEM increases Pe from 35% to 46% - almost as good as drilling 4 wells
  - ~1.4x increase in expected value of the Upper Cretaceous portfolio

- Binary CSEM interpretation assumed – performance will increase with EMGS standard integrated interpretation efforts

![Bar chart showing probability of at least 1 economic discovery with and without CSEM for different numbers of wells drilled.](chart.png)
Conclusions

• The stratigraphic nature of the Transform Margin play implies high risk
• The highest risks typically are seal integrity and charge
• De-risking with seismic DHIs is notoriously difficult due to the strong response from low saturation hydrocarbons
• CSEM has improved – now is the time to implement in workflows!
• Integrating CSEM with seismic DHIs can de-risk seal and charge by distinguishing between high and low saturations
• Thus CSEM will help rank your prospect portfolio and significantly increase your chance of economic success
• CSEM enables success in the critical early exploration phase

Source: Alcocer et al., 2013-04, First Break vol. 31