A New Kinematic Tool for Petroleum System Modeling in Structurally Complex Margins: Application to the Chidley Basin, Labrador, Canada

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¹Beicip-Franlab, 232 av Napoléon Bonaparte, Rueil-Malmaison, 92500, France

2018 Conjugate Margins Conference – Halifax, Nova Scotia, August 19-22, 2018
1. Context
2. Workflow
3. Kinematic Restoration
4. Thermal Evolution
5. Source Rock Maturity
6. Pore Pressure Regime
7. Hydrocarbon Migration
8. Conclusion
CONTEXT
Following the resource assessments of the Flemish Pass area in 2015 and the Orphan Basin Area in 2016, Nalcor Energy and the Newfoundland and Labrador Department of Natural Resources (DNR) engaged Beicip-Franlab to conduct an independent resource assessment of the south Labrador offshore area (Chidley Basin).

Objectives of this project:
- Geological and geophysical data interpretation
- Basin analysis
- Play risk analysis
- Resource assessment

For the upcoming license round (NL16-CFB03- TBD).
A regional seismic section representative of the whole basin geology was chosen to understand and model the petroleum system in place.

A 2D stratigraphic analysis and seismic interpretation was performed.

Facies dress-up using combined well information and seismic geomorphological elements was performed as well.
Syn-rift Cretaceous continental deposits passing upward to a marine shelf dominated by erosion/bypass and depositional turbiditic systems at toe of slope.

Cenozoic systems mainly dominated by slope to basin floor fans sedimentation fed from a significant delta trapped higher on the shelf.

Late Eocene/Oligocene, gravity driven, listric faults system that traps large quantities of sand in numerous traps.

Late Oligocene current remodeling sedimentation in large silty dominated contourites.
Classic Basin Modeling Workflow

1. Present day model building
   Stratigraphy, facies and source rock information
   Grid is vertical pillar based
   Faults are not explicitly represented

2. History of the deformation
   Vertical backstripping
   No shortening/extension

3. Forward simulation
   Thermal history, maturity timing, fluids pattern through time
   (water and hydrocarbon)

Frery et al., 2016
Limitations

- Geological objects and their geometrical complexity cannot be explicitly modeled
  - Listric faults
  - Compressive deformation fronts

- Movement along discontinuities and lateral displacement must be accounted for
  - Vertical shear backstripping must be replaced by a real step by step structural restoration

- Fault impact on pressure and fluid flow is not properly handled
A New Kinematic Tool for PSM in Structurally Complex Margins
A 4 Step Workflow

1. Present day model building

2. Step by step backward restoration

3. Computation of a mesh through time

4. Basin modeling forward simulation
KronosFlow: A New 2D Kinematic Tool

- To produce easily and rapidly consistent geological scenarios, for basin modeling and basin modelers

- **The key:** find the good balance between acceptable kinematics and productivity

- Accounts for:
  - Sediment **decompaction**
  - **Erosion**
  - Small **thickness variations**

- **Deformation** solutions:
  - Geometry driven
  - Mechanic driven
Compatibility with Basin Modeling

- **Mesh deformation** is guaranteed through a preservation of the topology through time
- Preserves mass balance and simulates transient phenomena
Fault Modeling

Representation of the gouge and damage zones through an implicit co-refining of adjacent meshes to control fluid flow across and along fault planes.
A New Kinematic Tool for PSM in Structurally Complex Margins
Model Stratigraphy and Lithofacies Definition

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Layers: Sandstone, Silt, Shale, Tight Shale, Shale SR, Upper Continental Crust

Vertical Exaggeration x4

0 25 50 km
Structural Reconstruction

- Step by step restoration based on a **7 step structural reconstruction** performed with LithoTect

- **Balanced** section

- **Paleobathymetries** are used as constraints at each restoration step
## Kinematic Restoration

### STRATIGRAPHY

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### LITHOLOGY

- **Sandstone**
- **Silt**
- **Shale**
- **Tight Shale**
- **Shale SR**
- **Upper Continental Crust**

*Vertical Exaggeration x4*

0 25 50 km

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127 Ma
A New Kinematic Tool for PSM in Structurally Complex Margins
A New Kinematic Tool for PSM in Structurally Complex Margins
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

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Layers:
- Sandstone
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Vertical Exaggeration x4

0 25 50 km

66 Ma
Kinematic Restoration

65 Ma

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Layers:
- Sandstone
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Vertical Exaggeration x4

0 25 50 km
### Kinematic Restoration

**A New Kinematic Tool for PSM in Structurally Complex Margins**

#### Stratigraphy

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#### Lithology

- **Sandstone**
- **Silt**
- **Shale**
- **Tight Shale**
- **Shale SR**
- **Upper Continental Crust**

#### Diagram Details

- **Vertical Exaggeration**: x4
- **Distance**: 0 - 50 km
- **Age**: 62 Ma
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

Layers | Period | Age (Ma)
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8 | | 38
7 | | 40
6 | KL | 42
5 | | 44
4 | | 46
3 | KE | 48
2 | | 50
1 | | 52

Vertical Exaggeration x4

0 25 50 km

Layers:
- Yellow: Sandstone
- Green: Silt
- Blue: Shale SR
- Purple: Shale SR
- Black: Tight Shale
- Red: Shale
- Gray: Upper Continental Crust

56 Ma
Kinematic Restoration

**STRATIGRAPHY**

- Layers: 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1
- Periods: Mioc Sup, Mioc Med, Mioc Inf, Olig, Eoc Sup, Eoc Inf-Med, Pal, KL, KE
- Ages (Ma): 54, 49, 45, 41, 39, 37, 34, 30, 27, 24, 20, 17, 14, 11, 8, 5, 3, 1

**LITHOLOGY**

- Sandstone, Silt, Shale, Tight Shale, Shale SR, Upper Continental Crust

**Vertical Exaggeration x4**

0 25 50 km

54 Ma
Kinematic Restoration

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- Sandstone
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51 Ma

Vertical Exaggeration x4

0 25 50 km

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Kinematic Restoration

45 Ma

STRATIGRAPHY

LITHOLOGY

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- Sandstone
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Vertical Exaggeration x4
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

LITHOLOGY

STRATIGRAPHY

Layers | Period     | Age (Ma) |
-------|------------|----------|
25     | Mioc Sup   | 8        |
24     | Mioc Med   | 3        |
23     | Mioc Inf   | 6.5      |
22     |            | 8        |
21     |            | 10       |
20     |            | 17       |
19     | Olig       | 24       |
18     |           | 27       |
17     |            | 30       |
16     | Mioc Inf   | 34       |
15     | Eoc Sup    | 39       |
14     | Eoc Inf-Med| 44       |
13     | Olig       | 45       |
12     | Eoc Inf-Med| 47       |
11     |           | 49       |
10     | Pal        | 51       |
9      | Pal        | 54       |
8      | Pal        | 58       |
7      |             | 62       |
6      | Pal        | 65       |
5      | KL         | 66       |
4      | KE         | 100      |
3      |            | 118      |
2      |            | 127      |
1      |            | 145      |

Layers:
- Sandstone
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Vertical Exaggeration x4

0 25 50 km

44 Ma
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

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Vertical Exaggeration x4

0 25 50 km

39 Ma
A New Kinematic Tool for PSM in Structurally Complex Margins
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

![Diagram of stratigraphy and lithology with layers and ages](image)

- **Layers:**
  - 25: Mioc Sup
  - 24: Mioc Med
  - 23: Mioc Inf
  - 22: Olig
  - 21: Eoc Sup
  - 20: Eoc Inf-Med
  - 19: Pal
  - 18: KL
  - 17: KE

- **Periods and Ages:**
  - Mioc Sup: 25-27 Ma
  - Mioc Med: 23-26 Ma
  - Mioc Inf: 21-24 Ma
  - Olig: 19-22 Ma
  - Eoc Sup: 17-20 Ma
  - Eoc Inf-Med: 15-18 Ma
  - Pal: 13-16 Ma
  - KL: 11-14 Ma
  - KE: 9-12 Ma

- **Lithology:**
  - Sandstone
  - Silt
  - Shale
  - Tight Shale
  - Shale SR
  - Upper Continental Crust

- **Vertical Exaggeration:** x4

- **Scale:** 0 to 50 km
Kinematic Restoration

24 Ma

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LITHOLOGY

STRATIGRAPHY

Vertical Exaggeration x4

0  25  50 km
Kinematic Restoration

### STRATIGRAPHY

### LITHOLOGY

#### Vertical Exagération x4

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A New Kinematic Tool for PSM in Structurally Complex Margins
A New Kinematic Tool for PSM in Structurally Complex Margins

Kinematic Restoration

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Vertical Exaggeration x4

0 25 50 km
A New Kinematic Tool for PSM in Structurally Complex Margins

Kinematic Restoration

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Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

STRATIGRAPHY

LITHOLOGY

Layers | Period | Age (Ma)
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24 | | 9
23 | Mioc Med | 6.5
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21 | Mioc Inf | 10
20 | | 17
19 | Olig | 24
18 | | 27
17 | | 30
16 | Eoc Sup | 34
15 | | 39
14 | | 44
13 | Eoc Inf-Med | 45
12 | | 47
11 | | 49
10 | | 51
9 | Pal | 54
8 | | 56
7 | | 62
6 | KL | 65
5 | | 66
4 | KE | 100
3 | | 118
2 | | 127
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Vertical Exaggeration x4

0 25 50 km

Particularly in Sandstone, Silt, Shale, Tight Shale, Shale SR, and Upper Continental Crust.
A New Kinematic Tool for PSM in Structurally Complex Margins
Kinematic Restoration

A New Kinematic Tool for PSM in Structurally Complex Margins

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Vertical Exaggeration x4

0 Ma
THERMAL EVOLUTION
A classic basin model simulation is first performed, coupling a lithospheric model with the sedimentary model. The lithospheric model represents the structural evolution of the crust and upper mantle during the rifting phase. An extraction of the heat flow values at the base of the sedimentary model at various location is performed to be applied on the unstructured model.
A New Kinematic Tool for PSM in Structurally Complex Margins
Thermal Regime

TEMPERATURE

VITRINITE REFLECTANCE

118 Ma

A New Kinematic Tool for PSM in Structurally Complex Margins
A New Kinematic Tool for PSM in Structurally Complex Margins
Thermal Regime

TEMPERATURE

VITRINITE REFLECTANCE

Temperature (°C)

Vitrinite Reflectance (%)

Vertical Exaggeration x4

A New Kinematic Tool for PSM in Structurally Complex Margins

66 Ma
Thermal Regime

A New Kinematic Tool for PSM in Structurally Complex Margins

TEMPERATURE

VITRINITE REFLECTANCE

0 25 50 km

Temperature (°C)

0 80 100 240

Vitrinite Reflectance (%)

0.5 1.0 1.5 2.0

Vertical Exaggeration x4

65 Ma
Thermal Regime

A New Kinematic Tool for PSM in Structurally Complex Margins

62 Ma

Temperature (°C)

Vitrinite Reflectance (%)
Thermal Regime

A New Kinematic Tool for PSM in Structurally Complex Margins
Thermal Regime

54 Ma

A New Kinematic Tool for PSM in Structurally Complex Margins