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

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Content

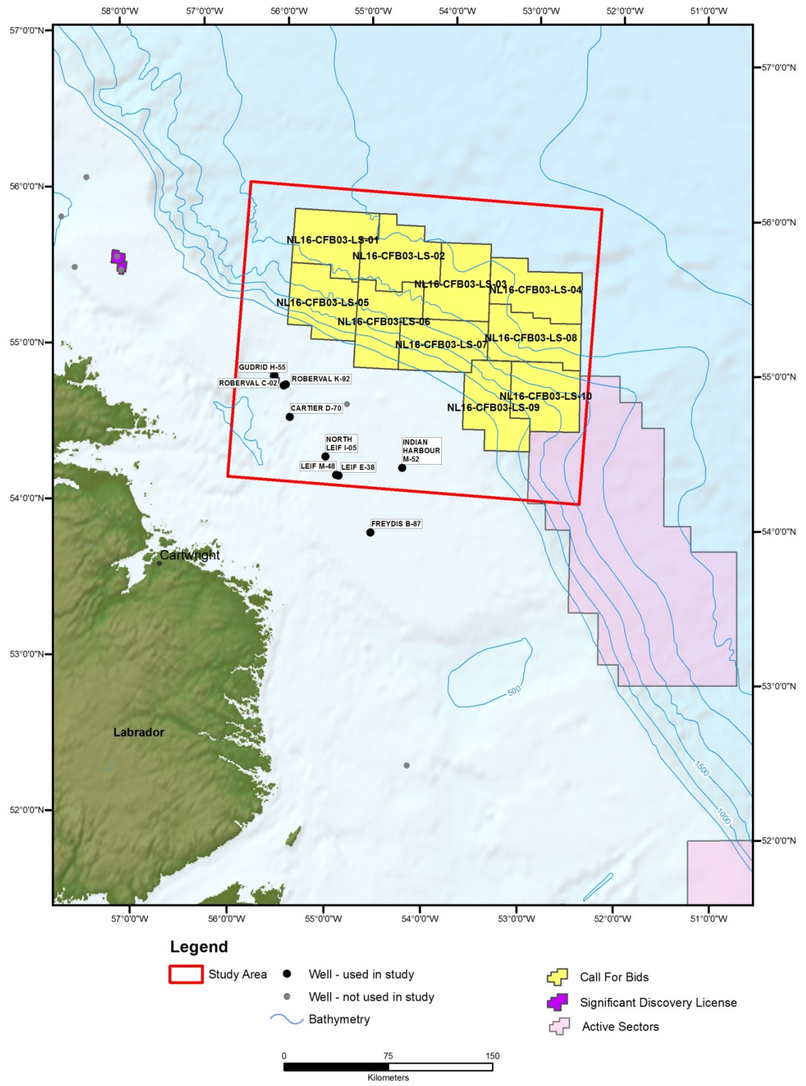
CONTEXT

Resource Assessment of the **Chidley Basin**

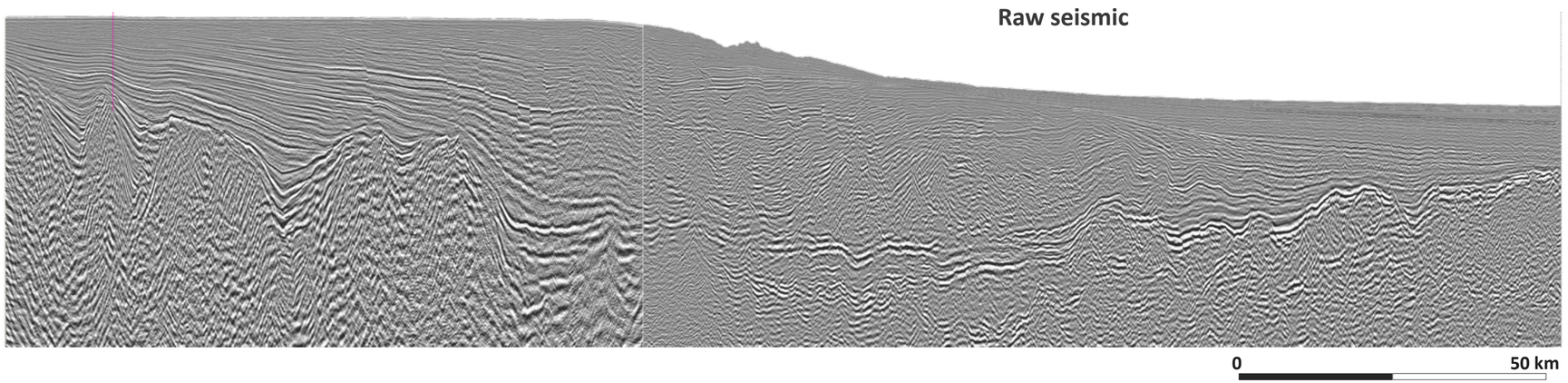
- Following the resource assessments of the Flemish Pass area in 2015 and the Orphan Basin Area in 2016, **Nalcor Energy** and the **Newfoundland and Labrador Department of Natural Resources (DNR)** engaged **Beicip-Franlab** to conduct an independent resource assessment of the south Labrador offshore area (Chidley Basin).

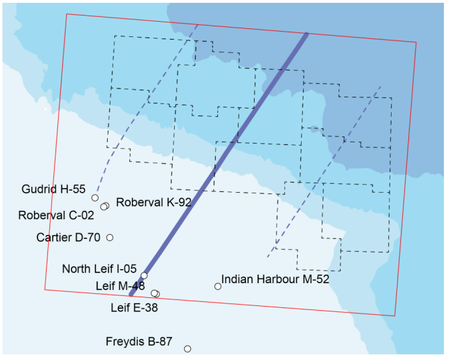
- Objectives of this project:
  - Geological and geophysical data interpretation
  - Basin analysis
  - Play risk analysis
  - Resource assessment

- For the upcoming license round (NL16-CFB03- TBD).



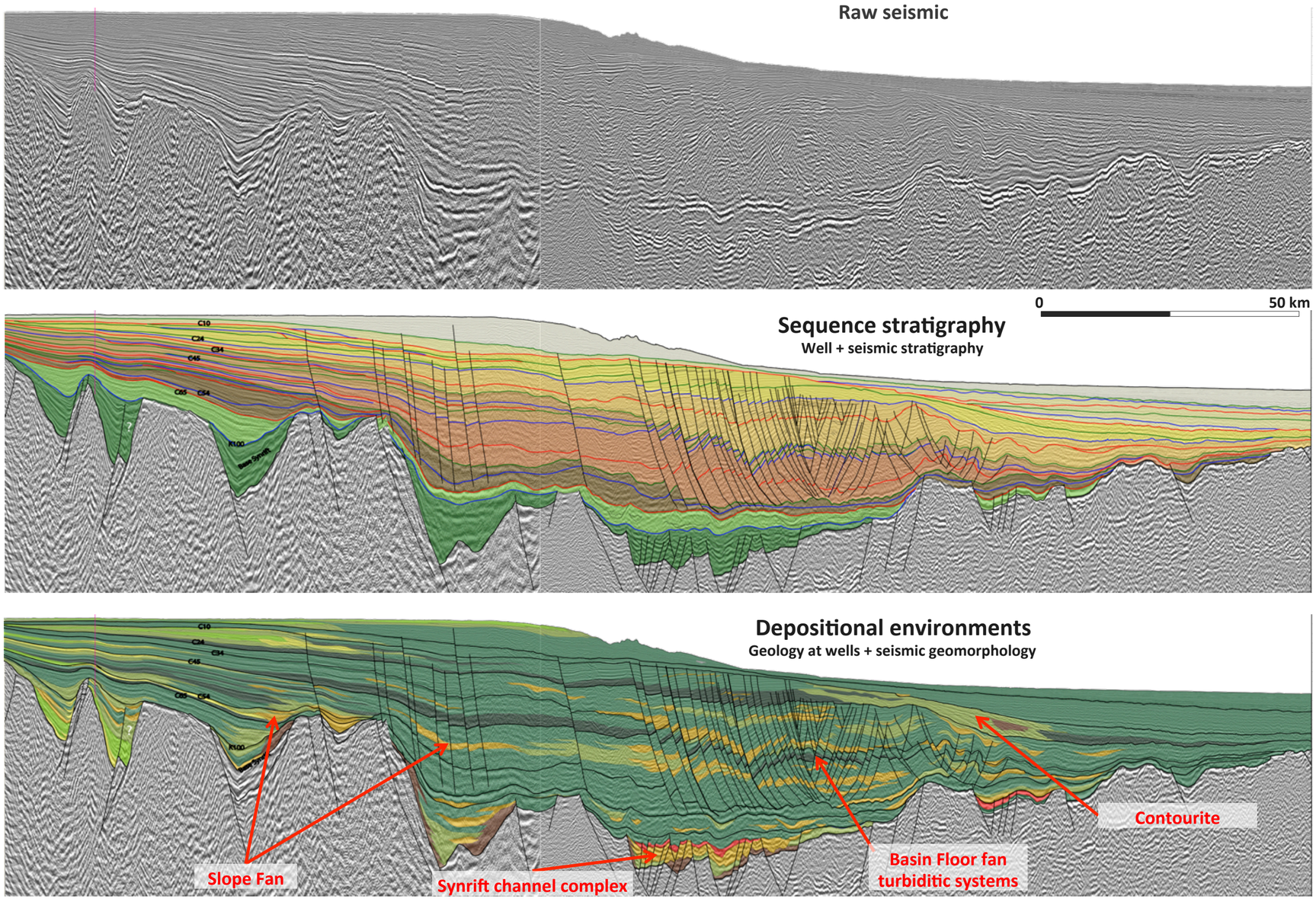
Reference 2D Section

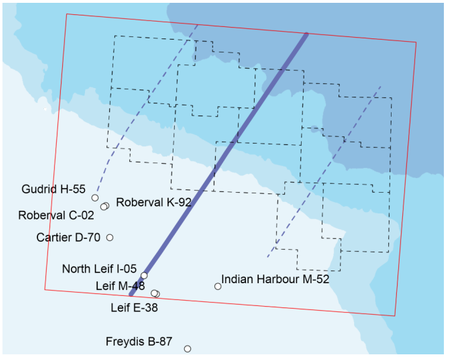




- A regional seismic section representative of the whole basin geology was chosen to understand and model the petroleum system in place.
- A 2D stratigraphic analysis and seismic interpretation was performed.
- Facies dress-up using combined well information and seismic geomorphological elements was performed as well.

Reference 2D Section





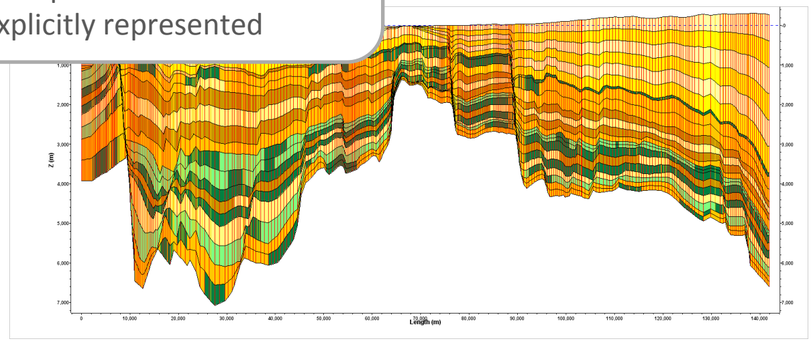
- Syn-rift Cretaceous continental deposits passing upward to a marine shelf dominated by erosion/bypass and depositional turbiditic systems at toe of slope.
- Cenozoic systems mainly dominated by slope to basin floor fans sedimentation fed from a significant delta trapped higher on the shelf.
- Late 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

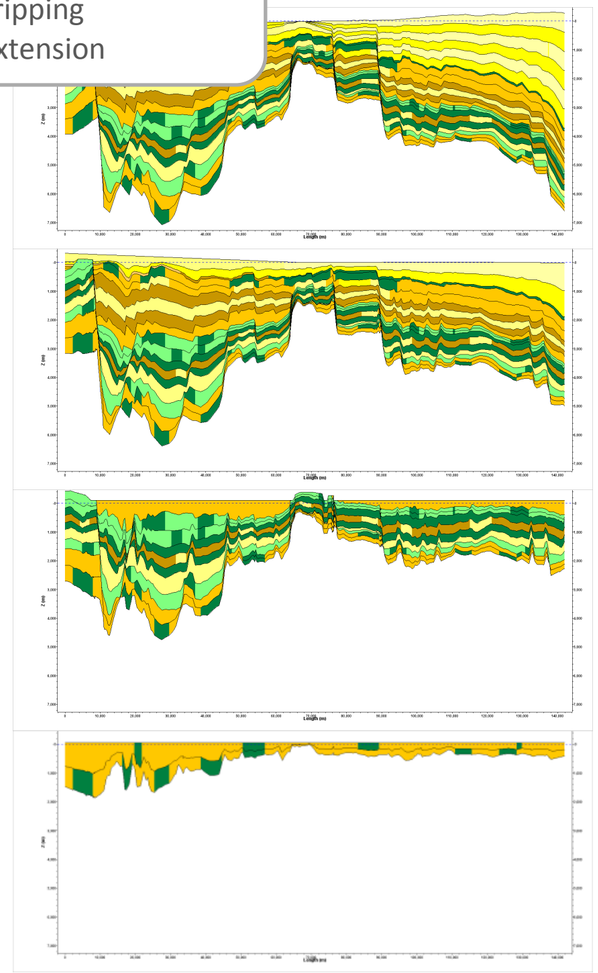
Stratigraphy, facies and source rock information
Grid is vertical pillar based
Faults are not explicitly represented



2

History of the deformation

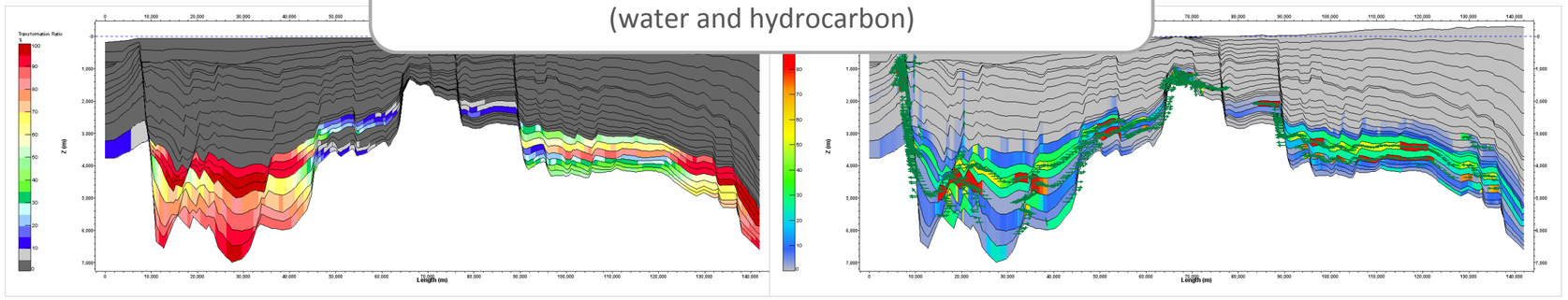
Vertical backstripping
No shortening/extension



3

Forward simulation

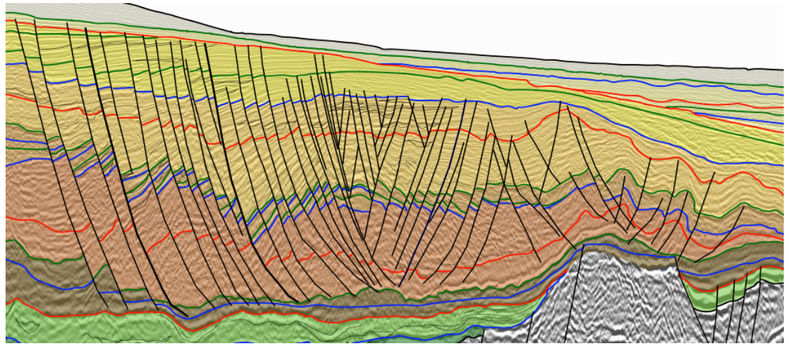
Thermal history, maturity timing, fluids pattern through time
(water and hydrocarbon)



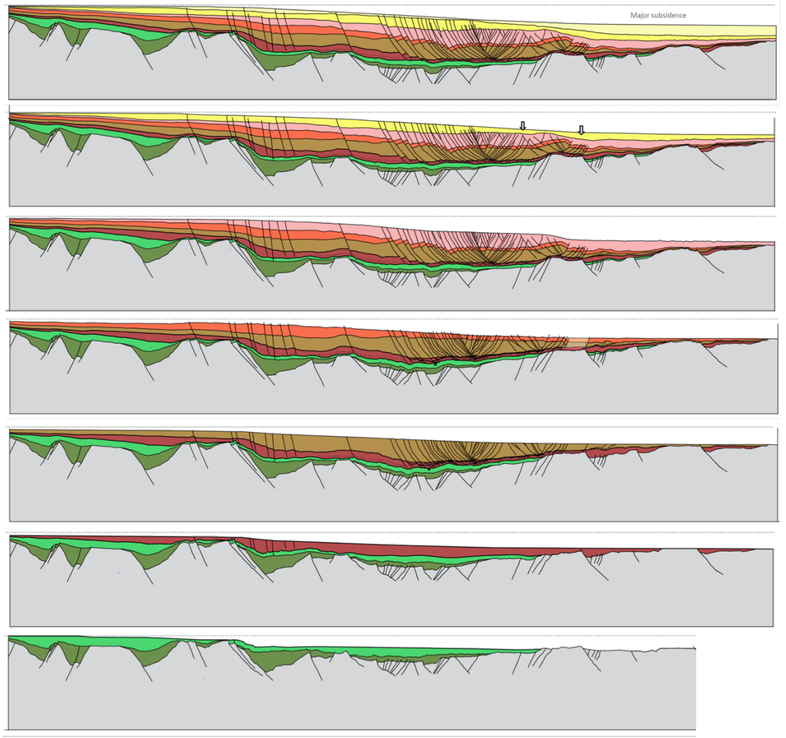
Frery *et al.,* 2016

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

WORKFLOW

A 4 Step Workflow

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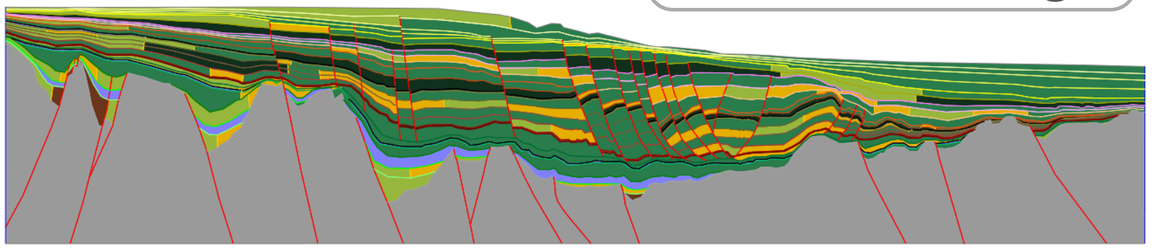
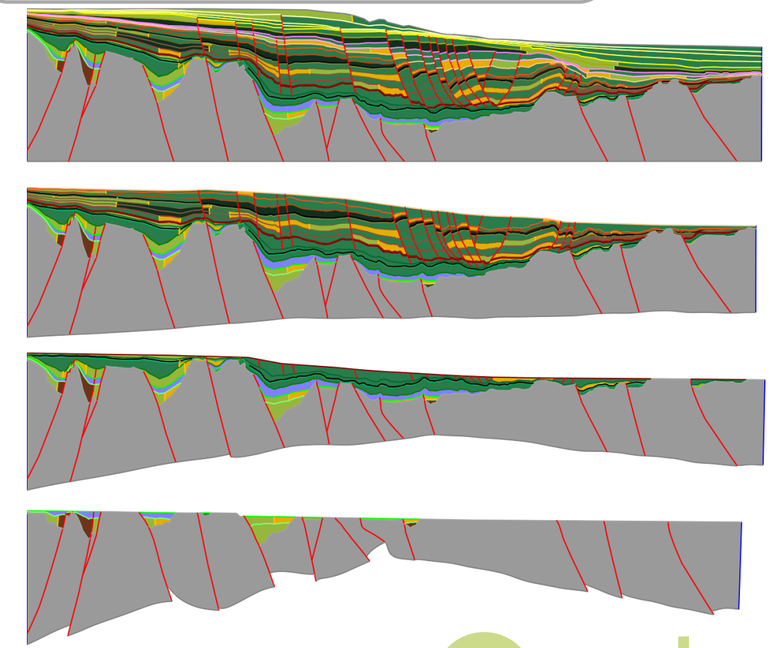
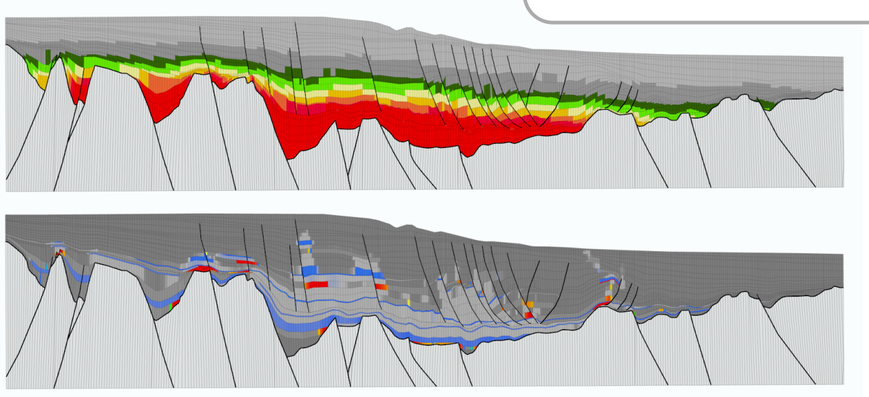


2 **Step by step backward restoration**



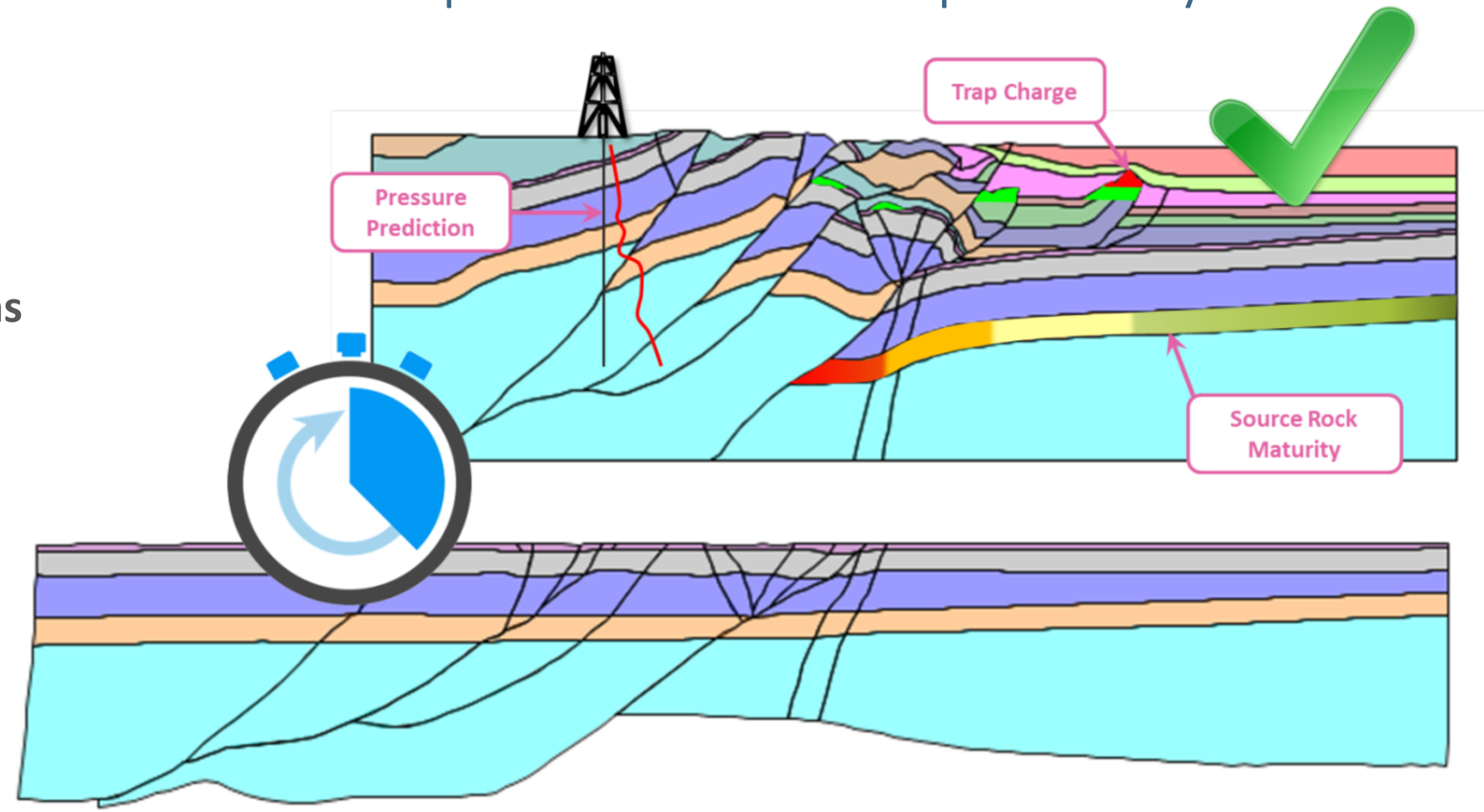
3 **Computation of a mesh through time**

4 **Basin modeling forward simulation**



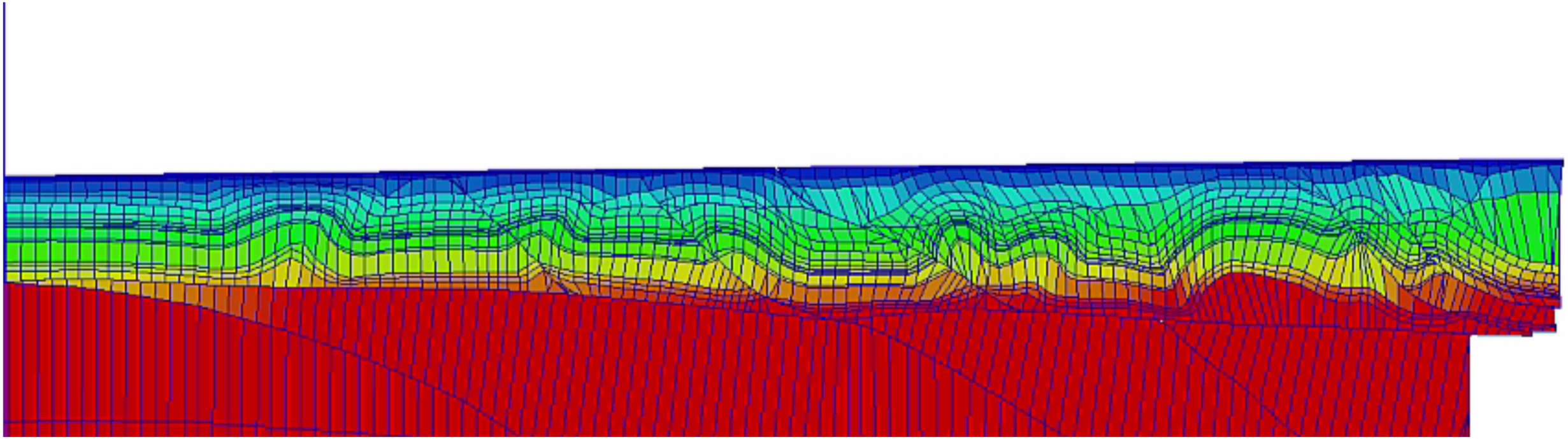
KronosFlow: A New 2D Kinematic Tool

- 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**



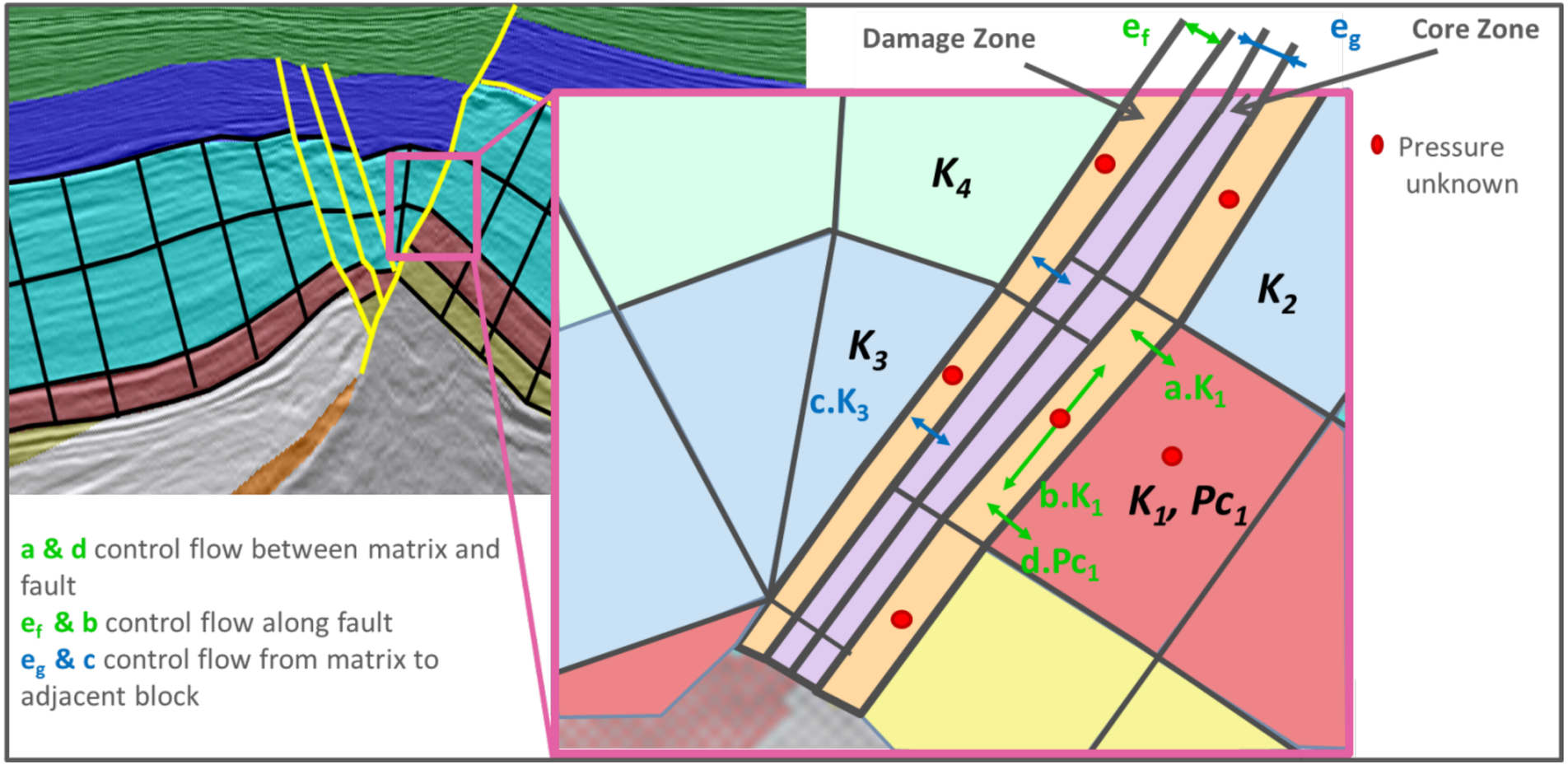
Compatibility with **Basin Modeling**

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



Fault Modeling

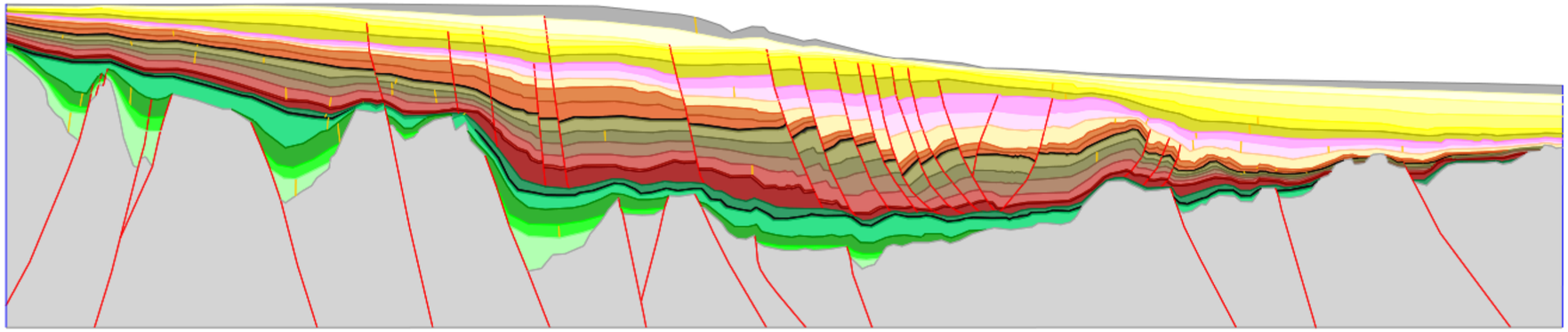
- Representation of the gouge and damage zones through an implicit co-refining of adjacent meshes to control fluid flow across and along fault planes



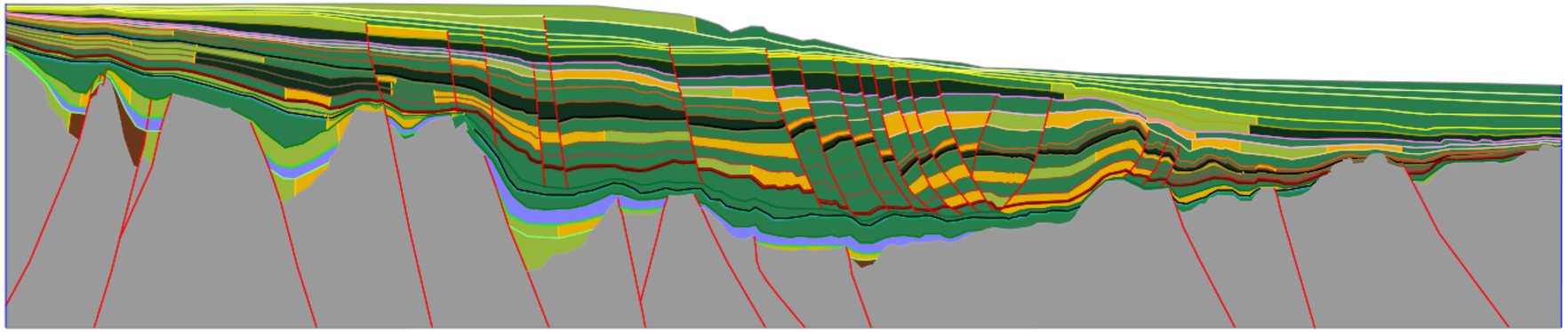
KINEMATIC RESTORATION

Model **Stratigraphy** and **Lithofacies** Definition

STRATIGRAPHY



LITHOLOGY



Vertical Exageration x4

0 25 50 km

Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
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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
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6	KL	65
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4	KE	100
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- Sandstone
- Silt
- Shale
- Tight Shale
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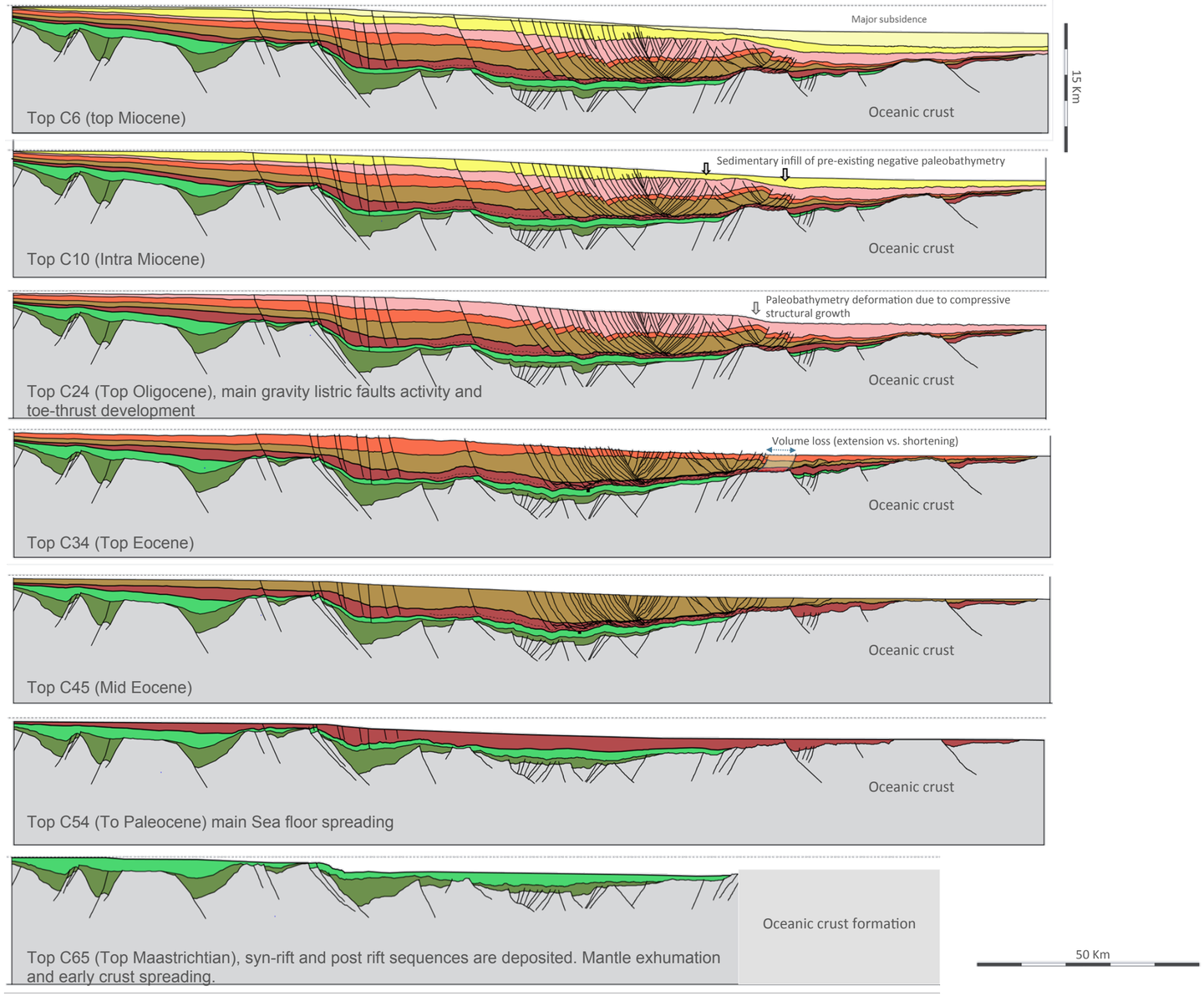
Structural **Reconstruction**

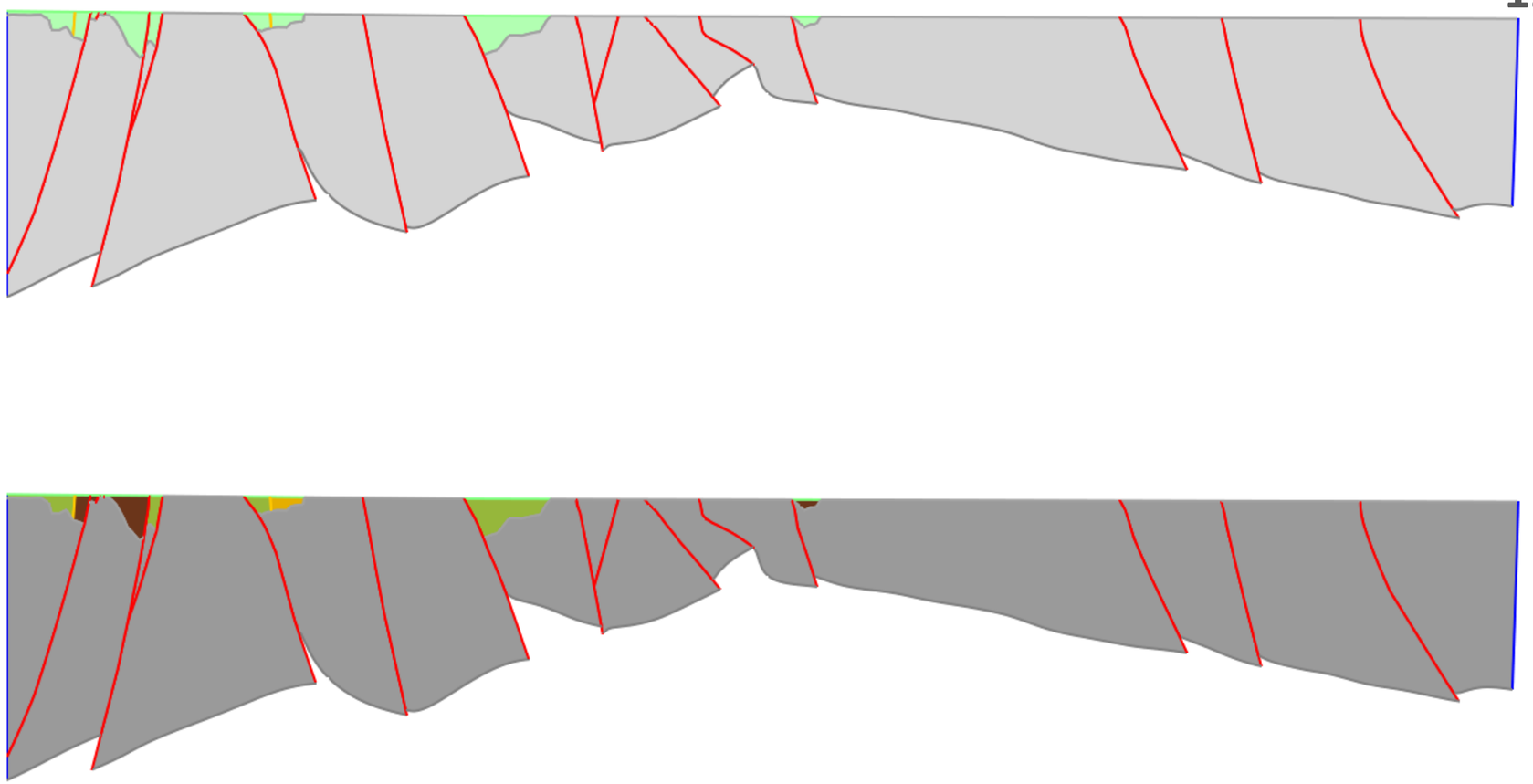
- Step by step restoration based on a **7 step structural reconstruction** performed with LithoTect
- **Balanced** section
- **Paleobathymetries** are used as constraints at each restoration step



Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



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Kinematic Restoration

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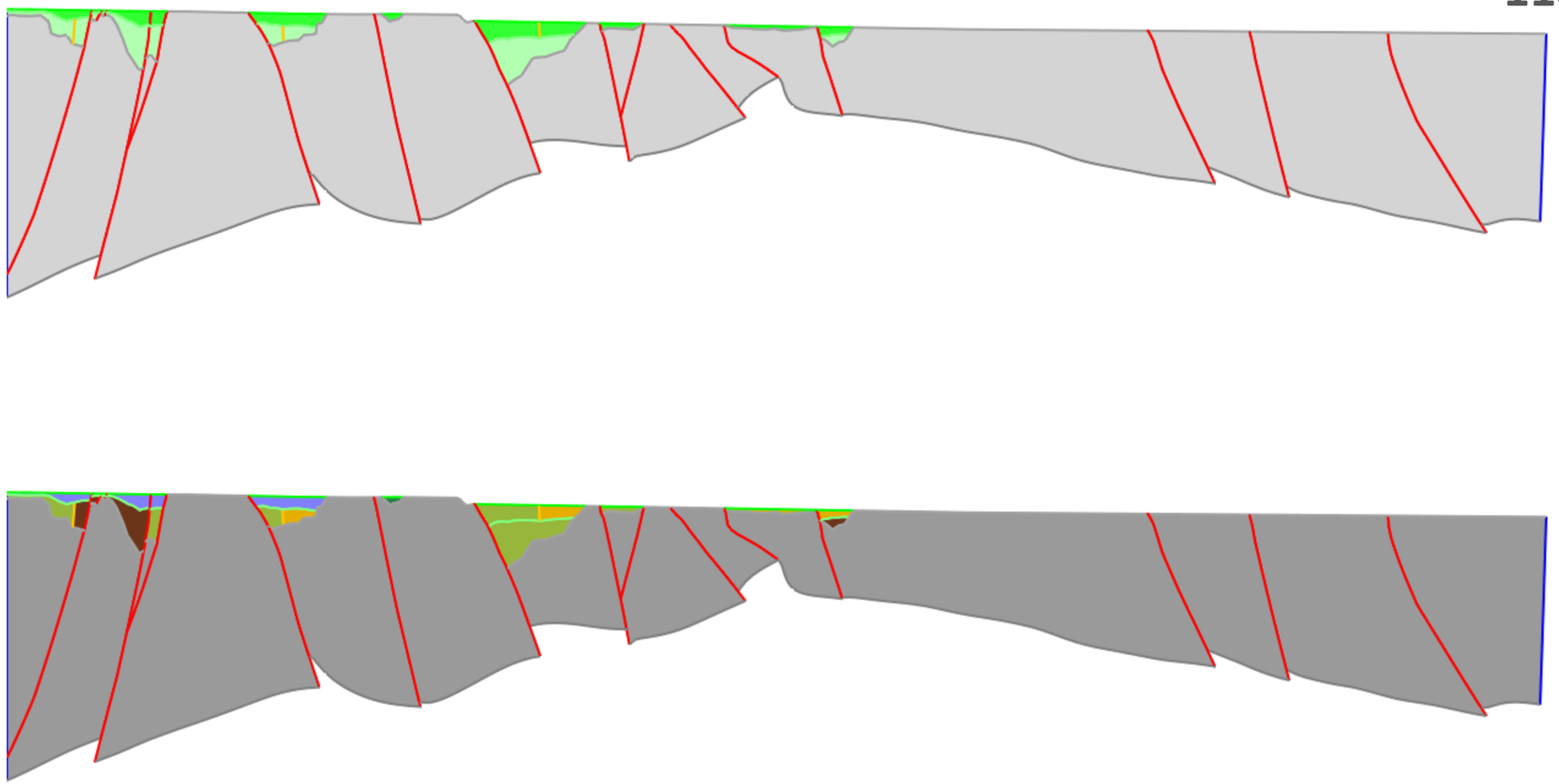

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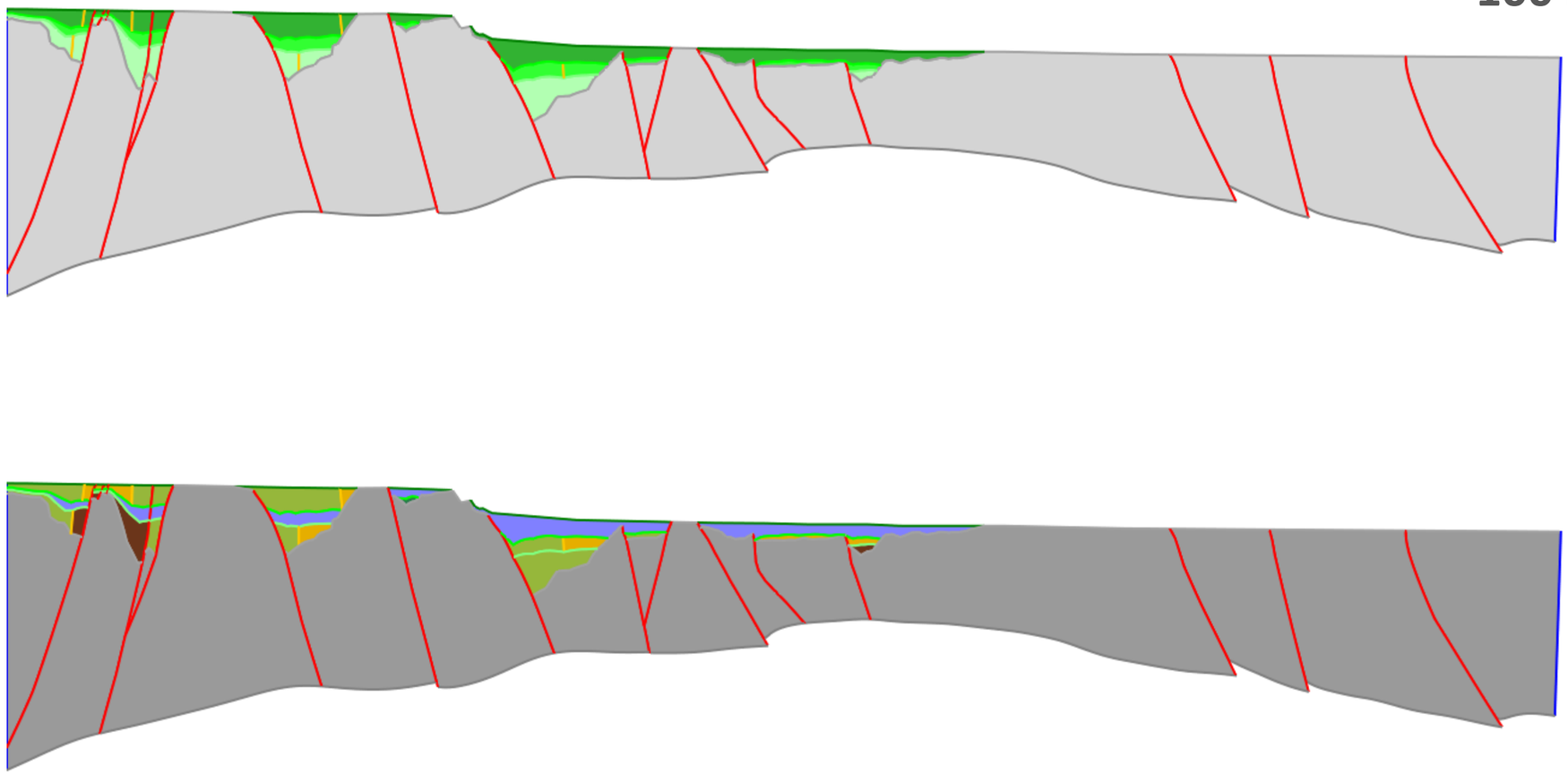

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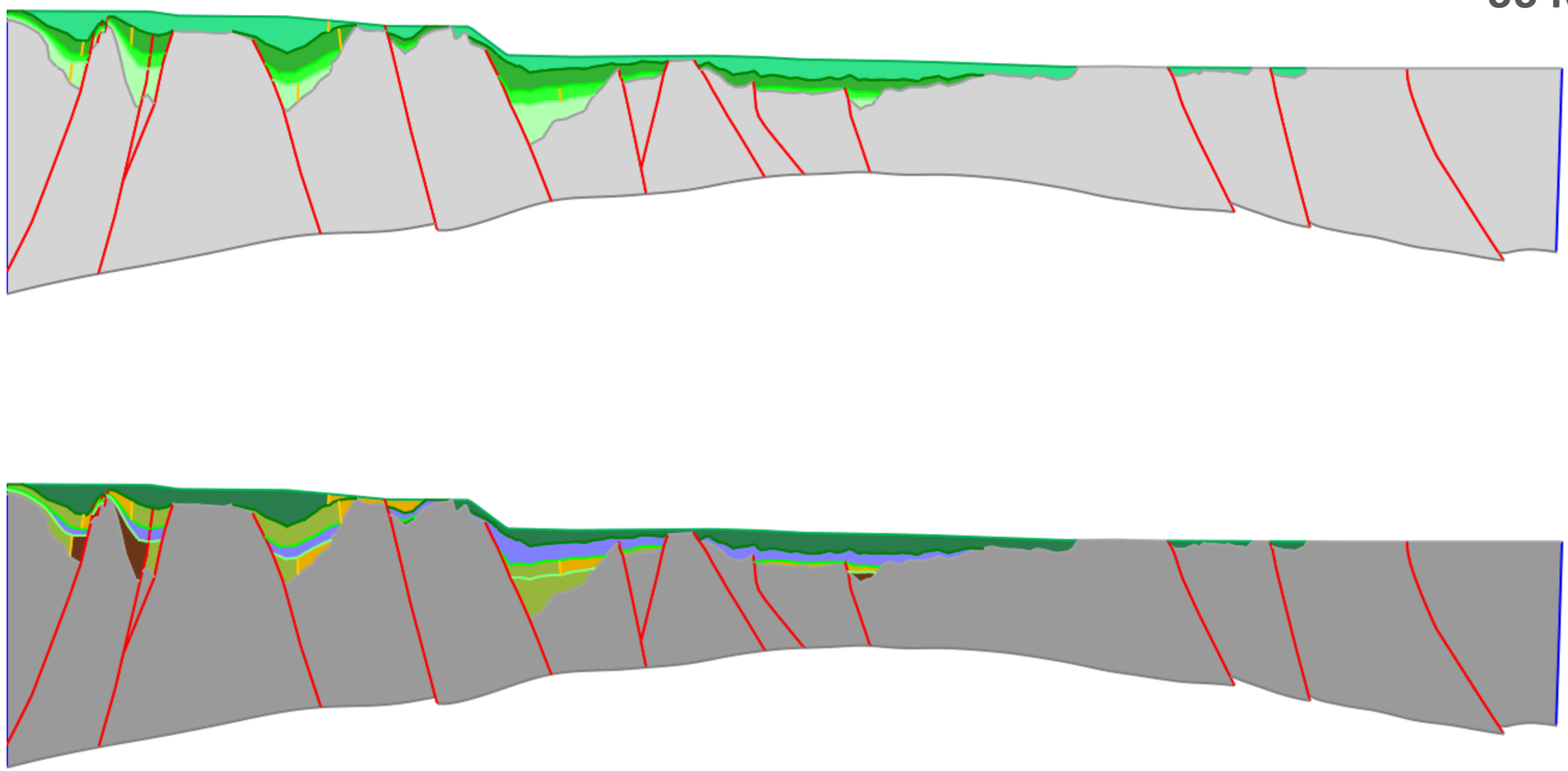
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

66 Ma



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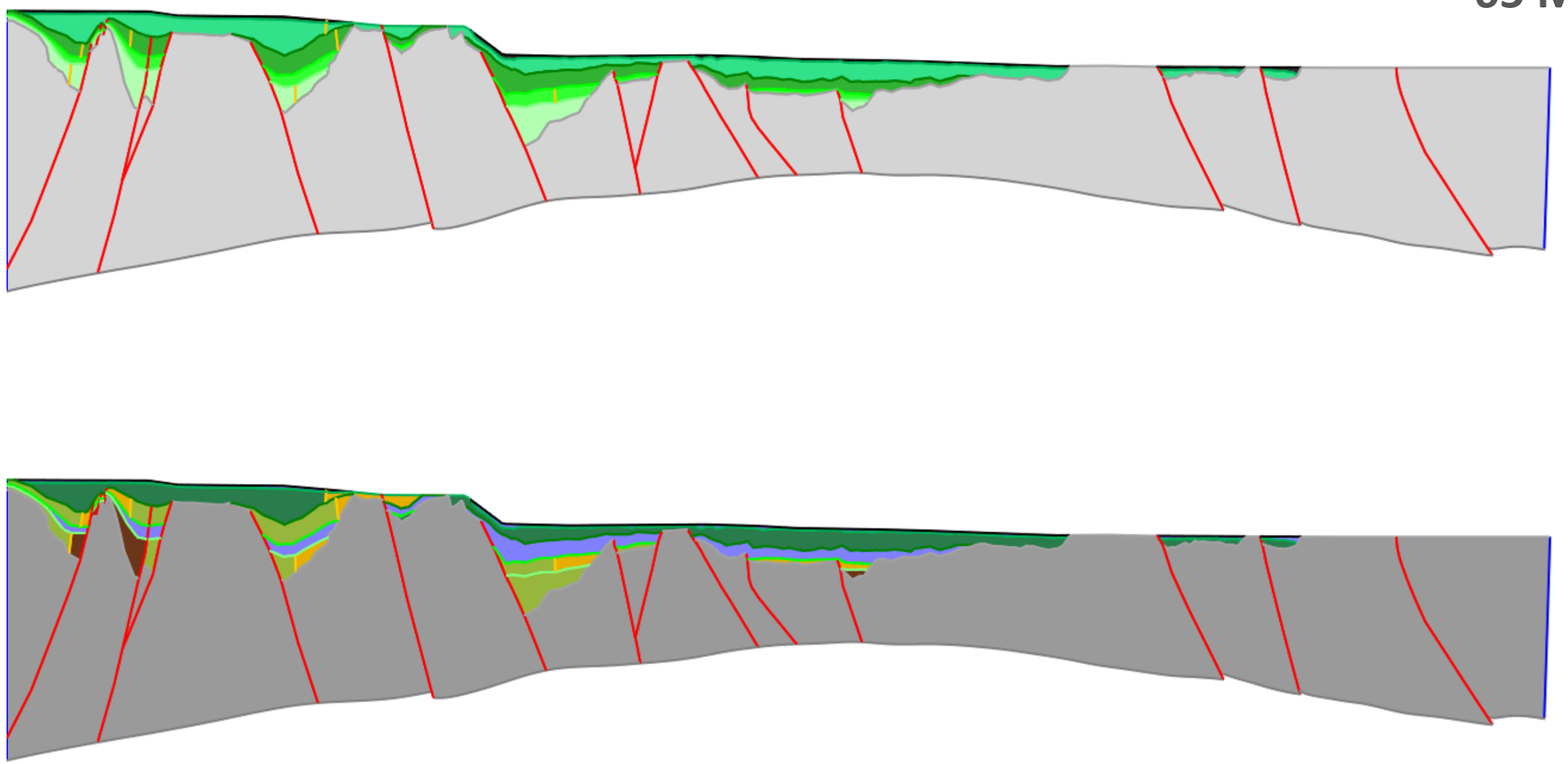
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

65 Ma



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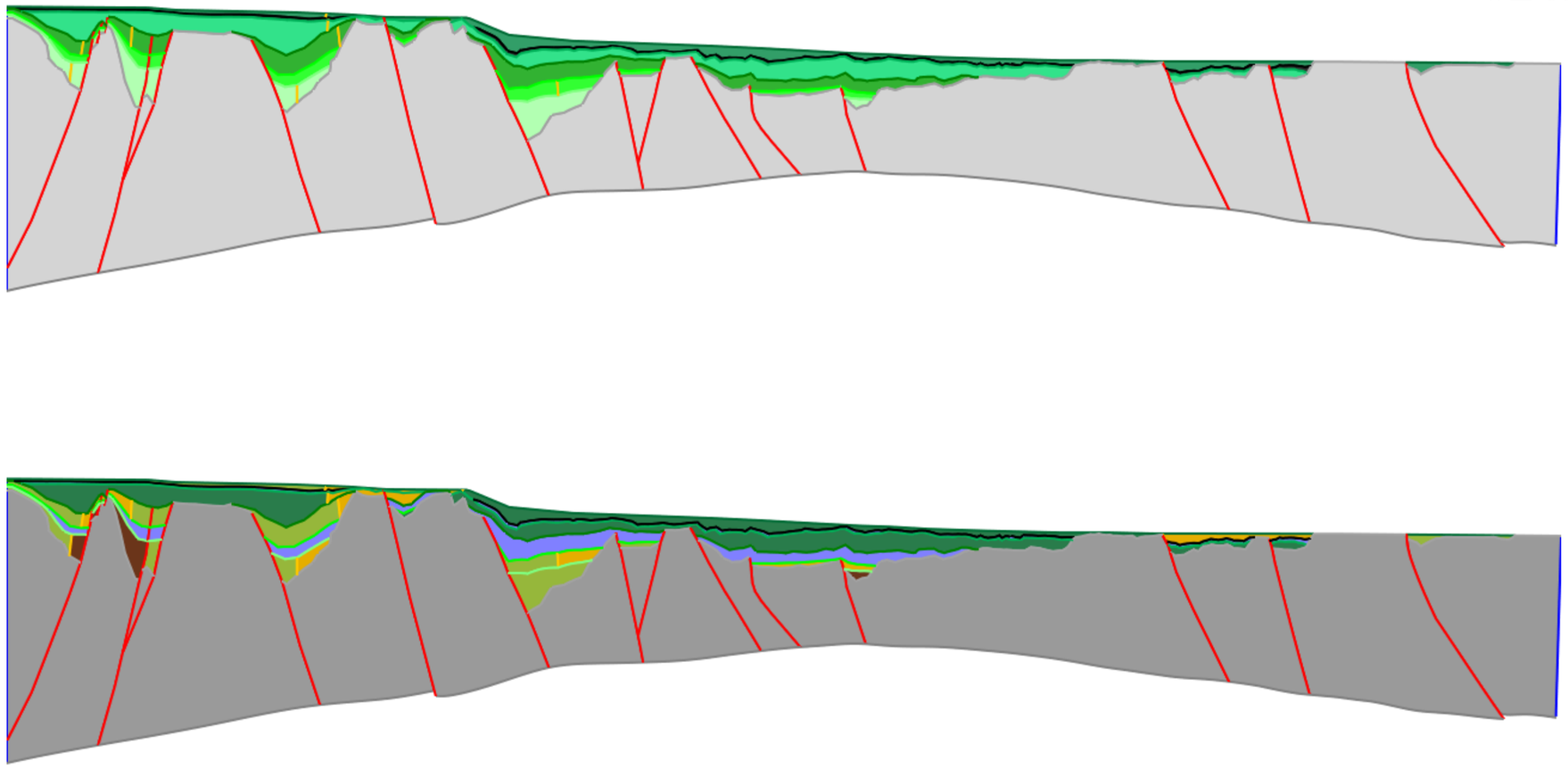
STRATIGRAPHY

LITHOLOGY

62 Ma



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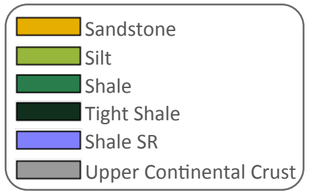

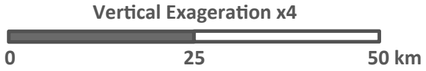

Kinematic Restoration

STRATIGRAPHY

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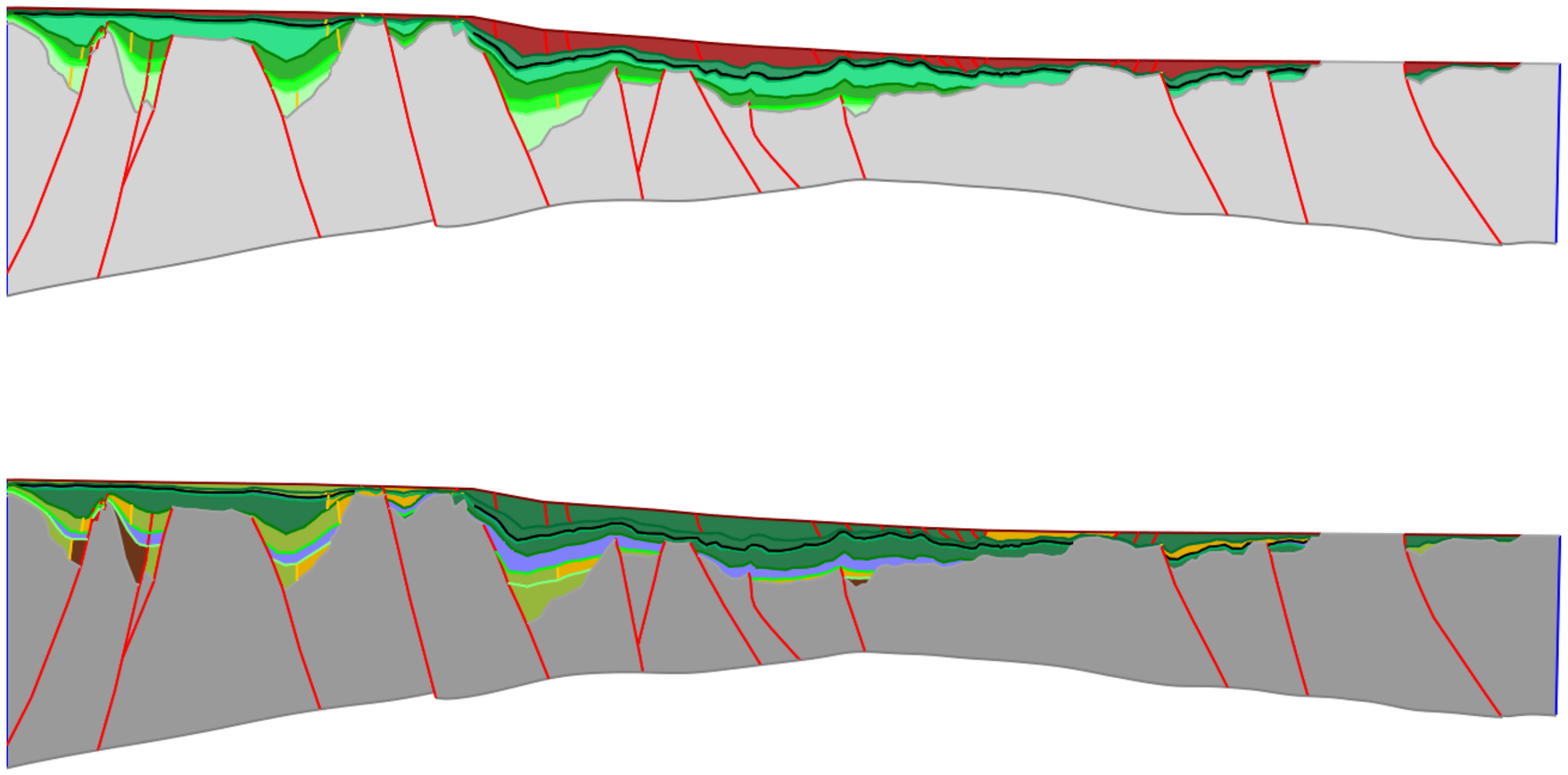

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Kinematic Restoration

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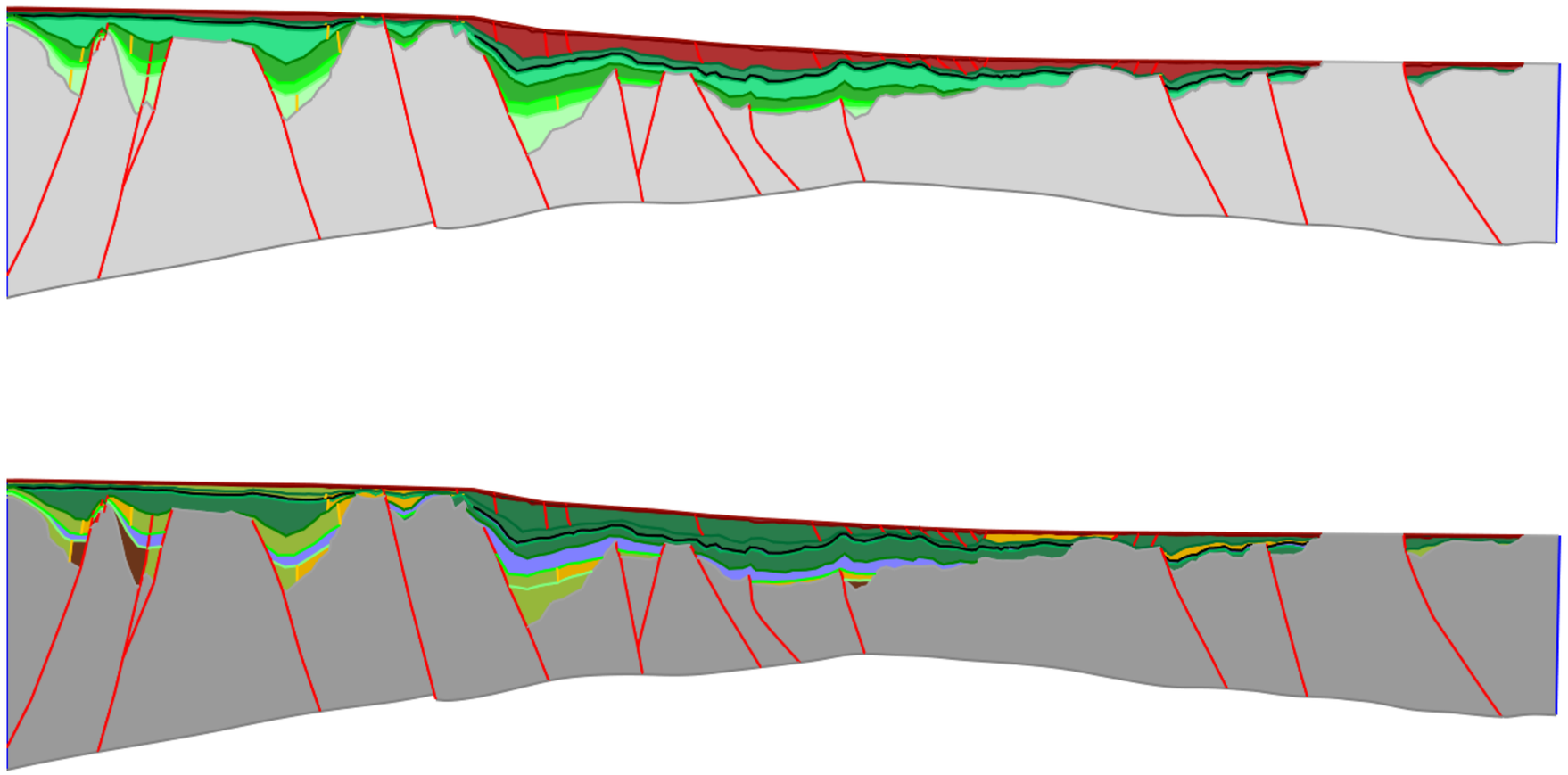

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STRATIGRAPHY

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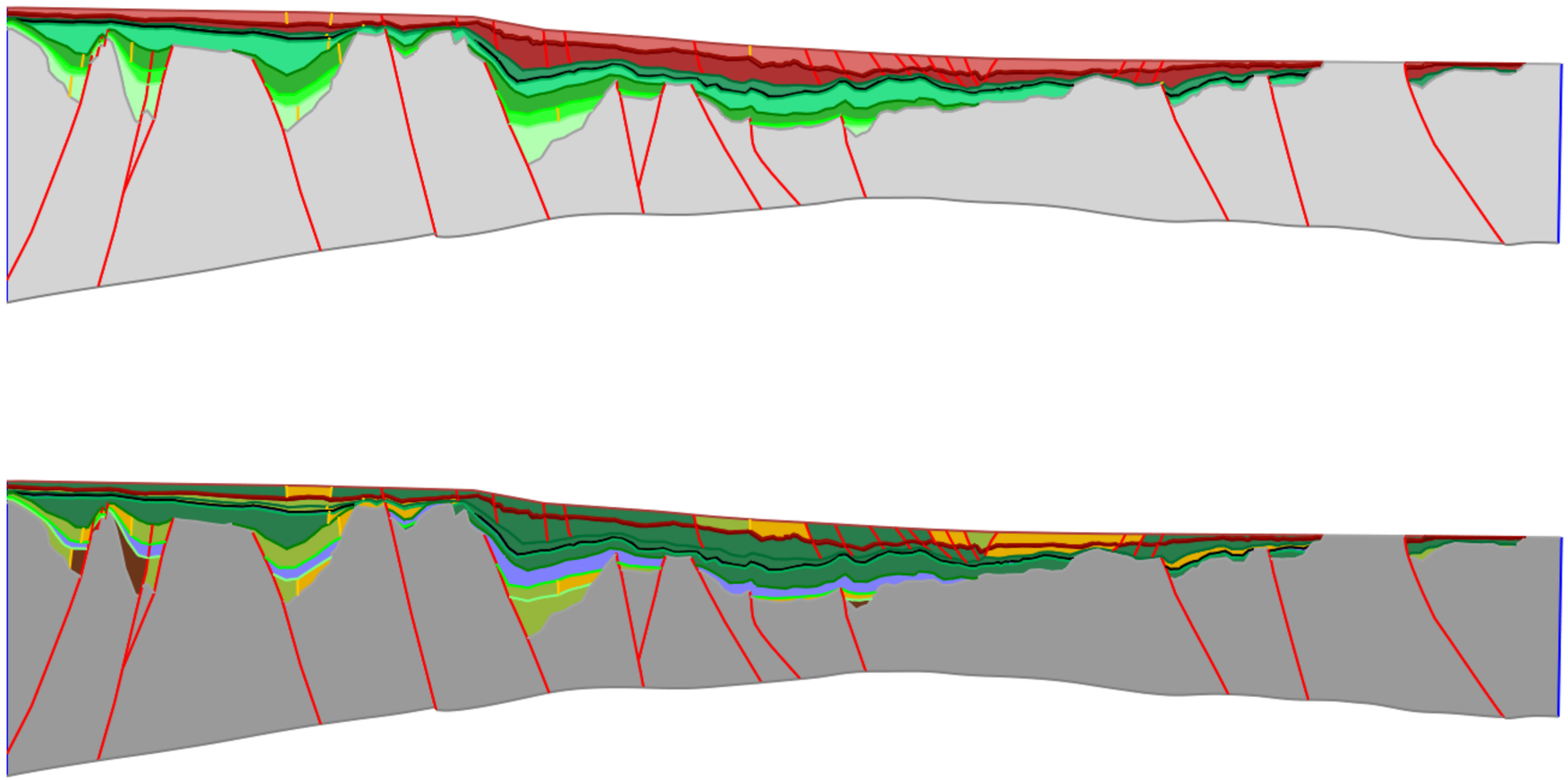
51 Ma



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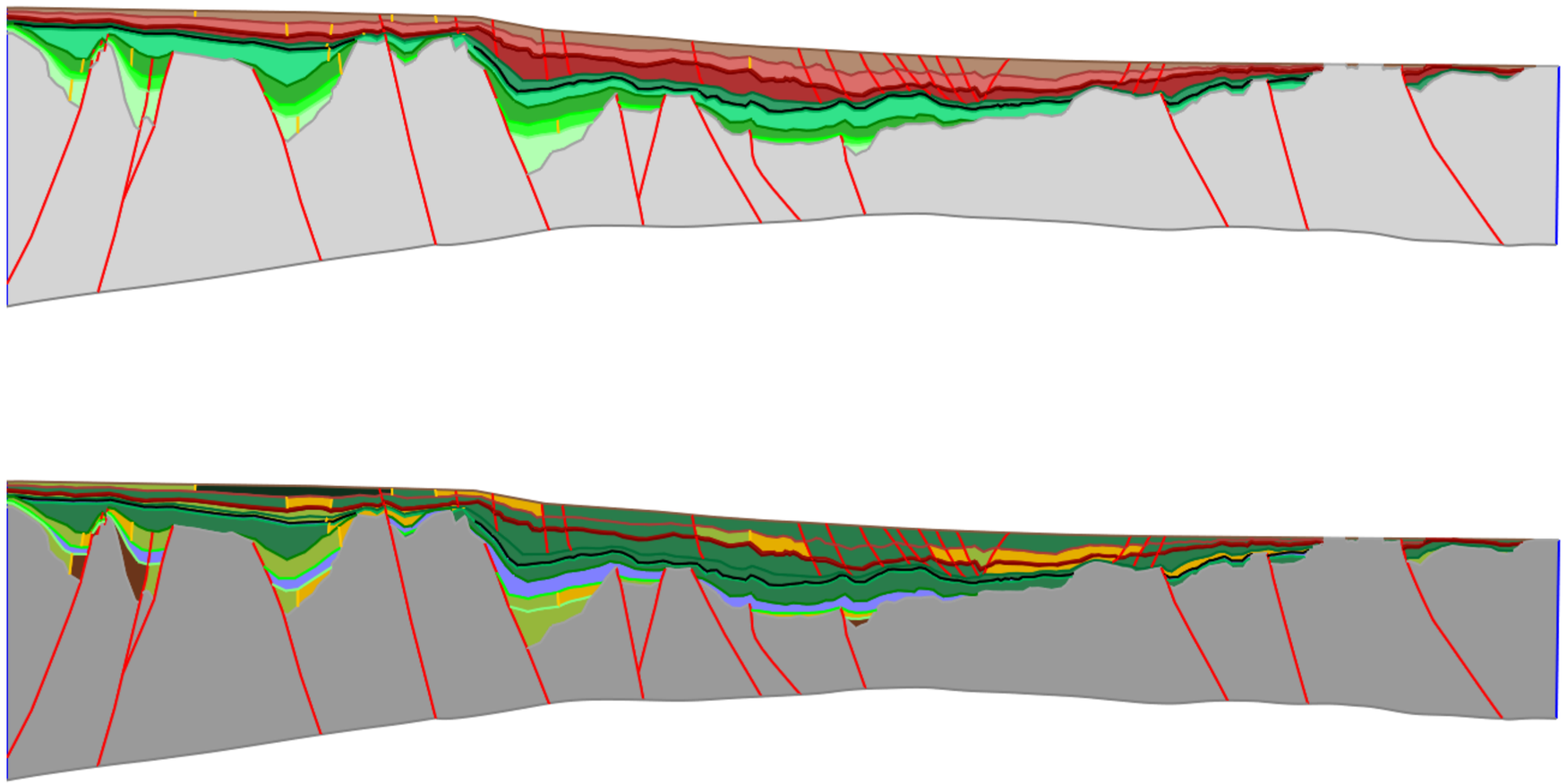

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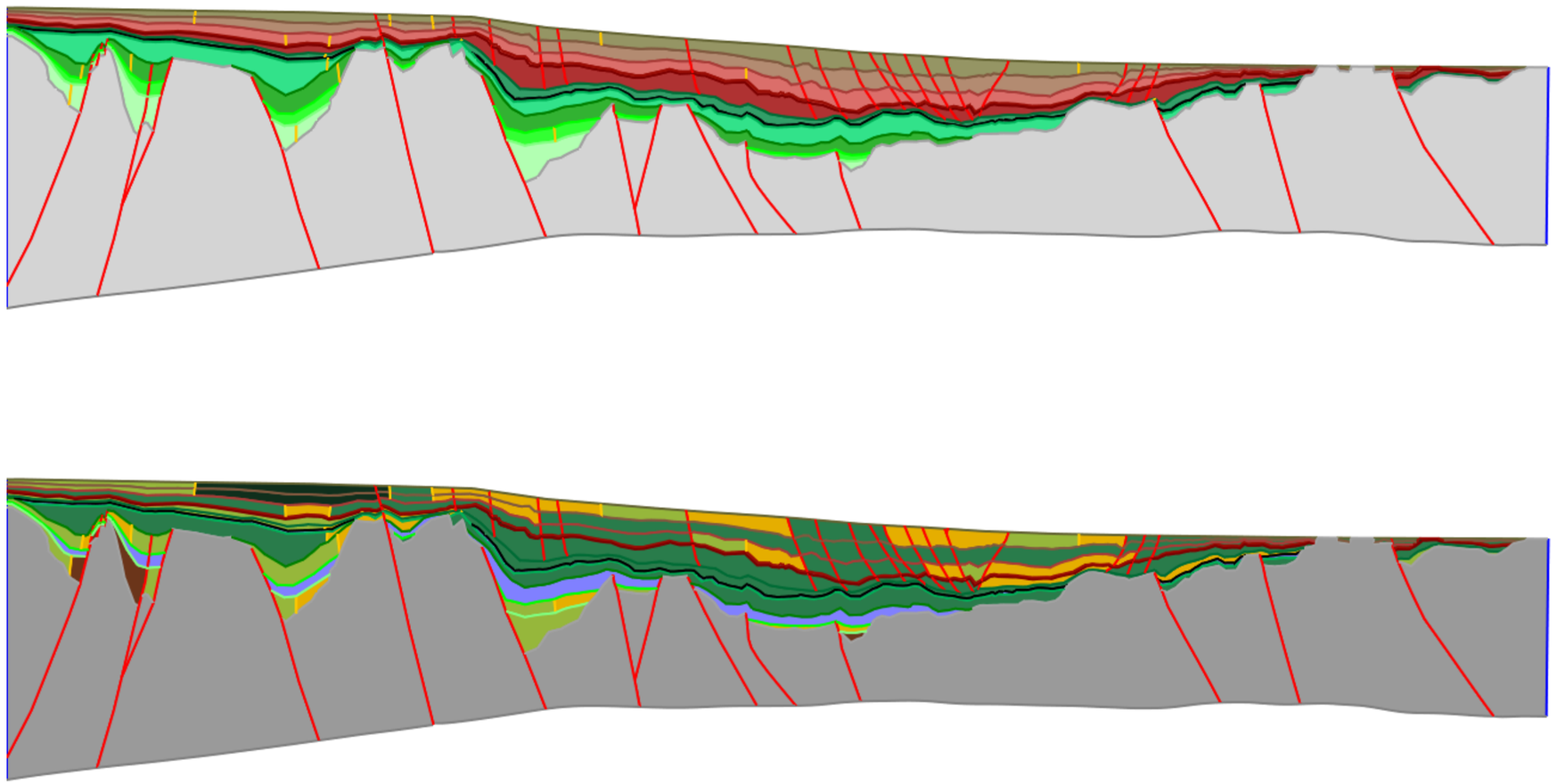
47 Ma



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9	Pal	54
8		56
7		62
6	KL	65
5		66
4	KE	100
3		118
2		127
1		145

Sandstone
Silt
Shale
Tight Shale
Shale SR
Upper Continental Crust

Vertical Exageration x4

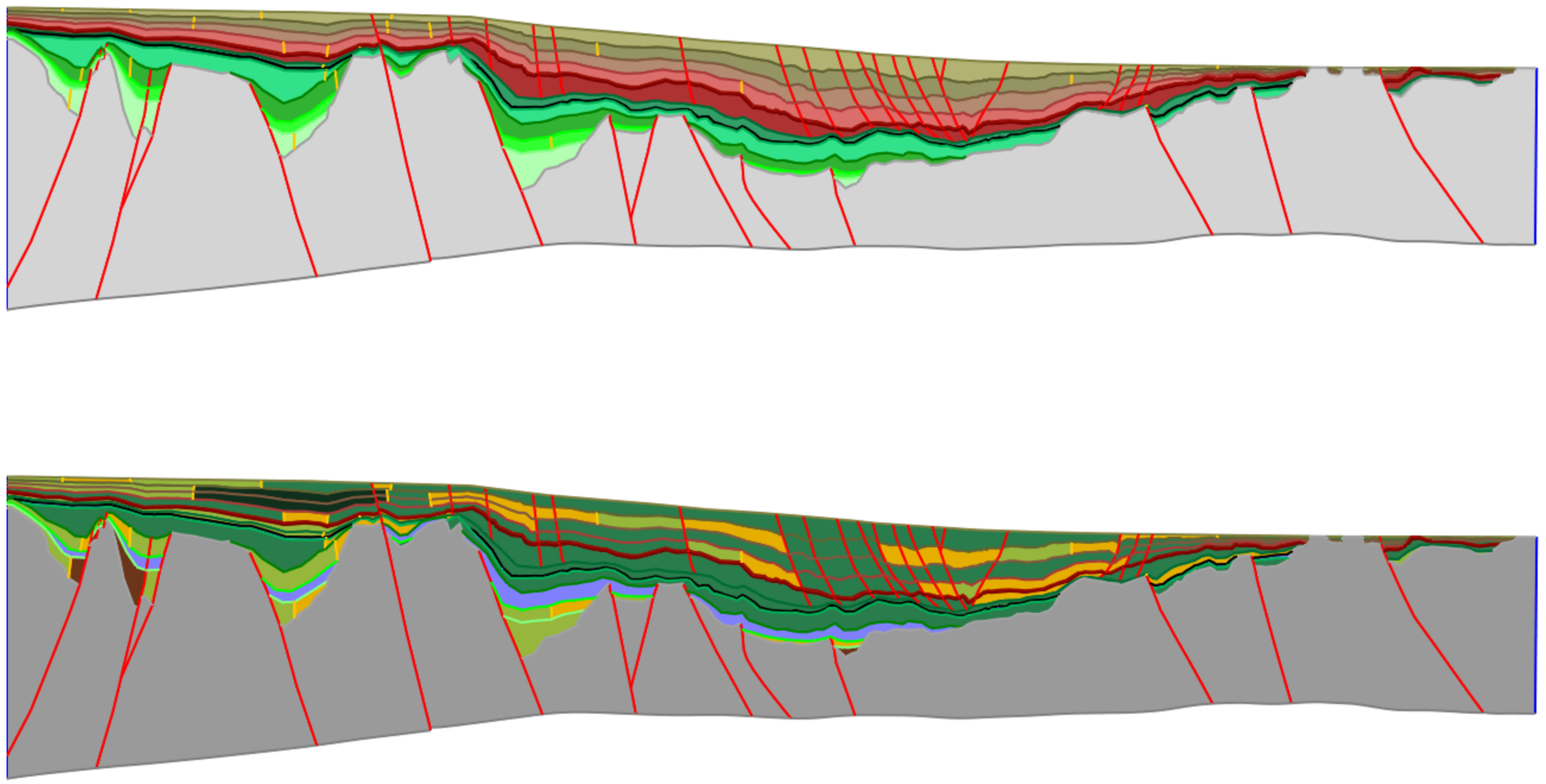
0 25 50 km

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

45 Ma



Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
23	Mioc Med	6.5
22		8
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
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6	KL	65
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- Sandstone
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Vertical Exageration x4

0 25 50 km

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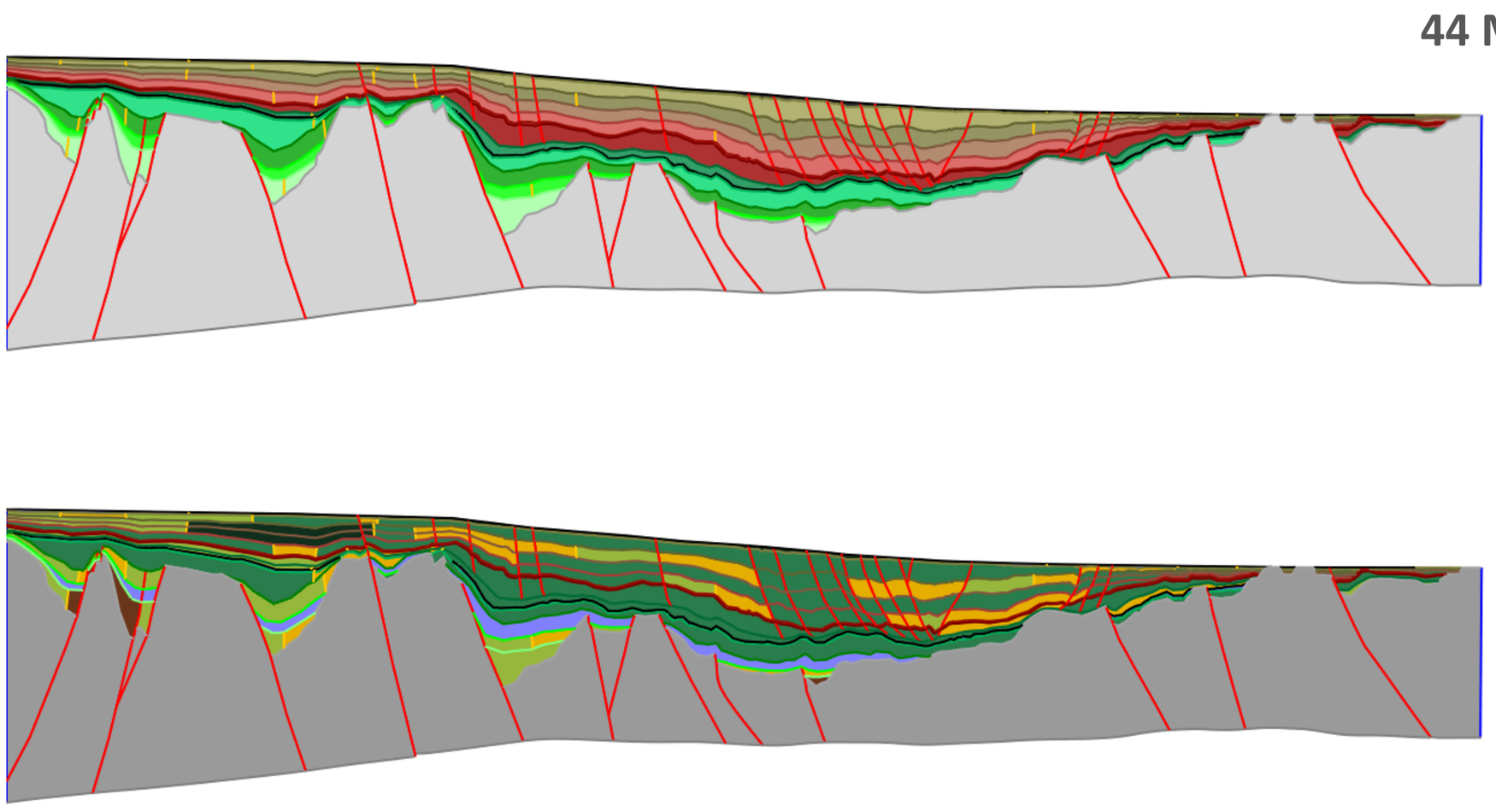
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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24		3
23	Mioc Med	6.5
22		8
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20		17
19	Olig	24
18		27
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16	Eoc Sup	34
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14		44
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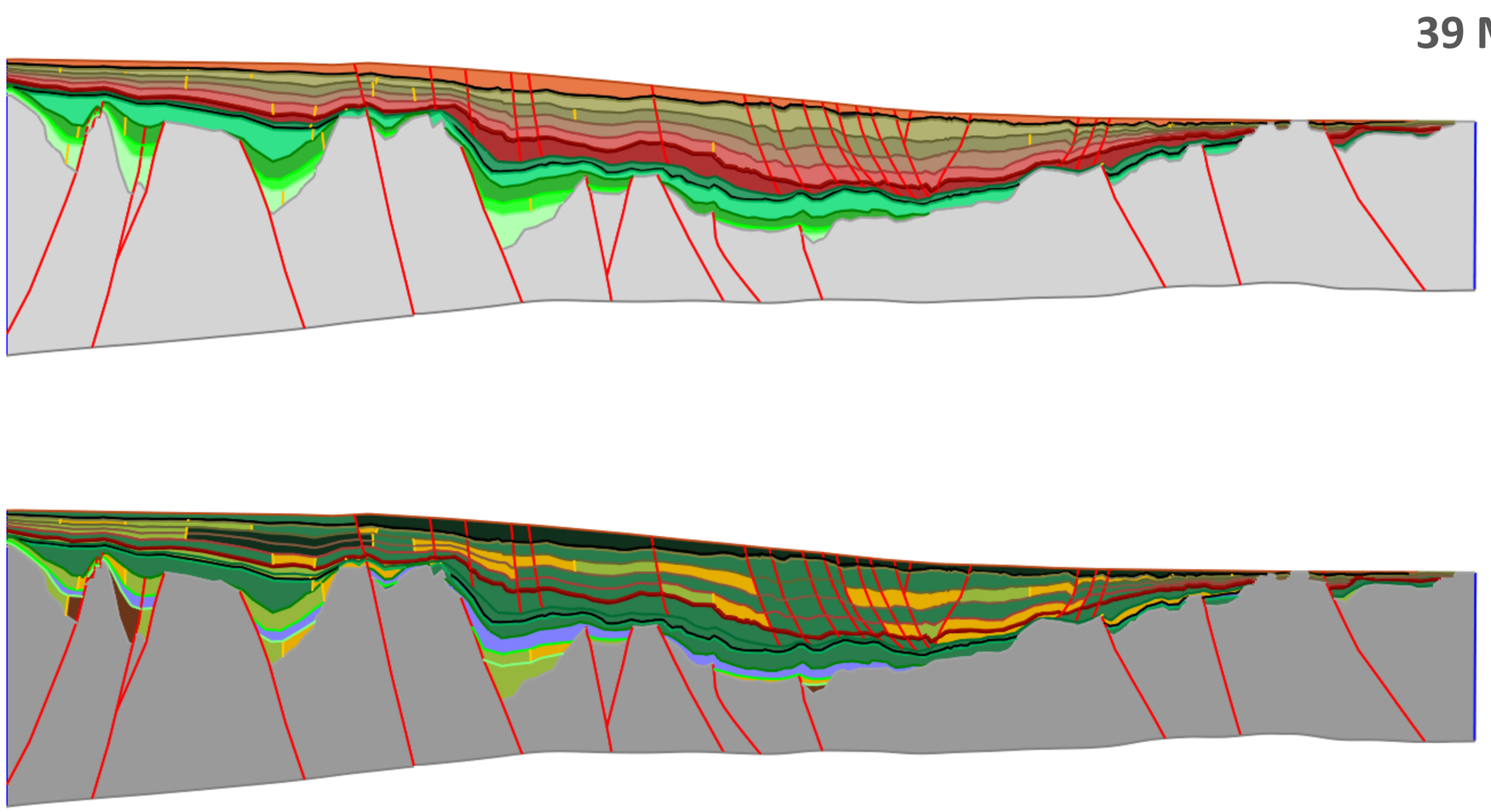
- Shale SR
- Upper Continental Crust

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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24		3
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19	Olig	24
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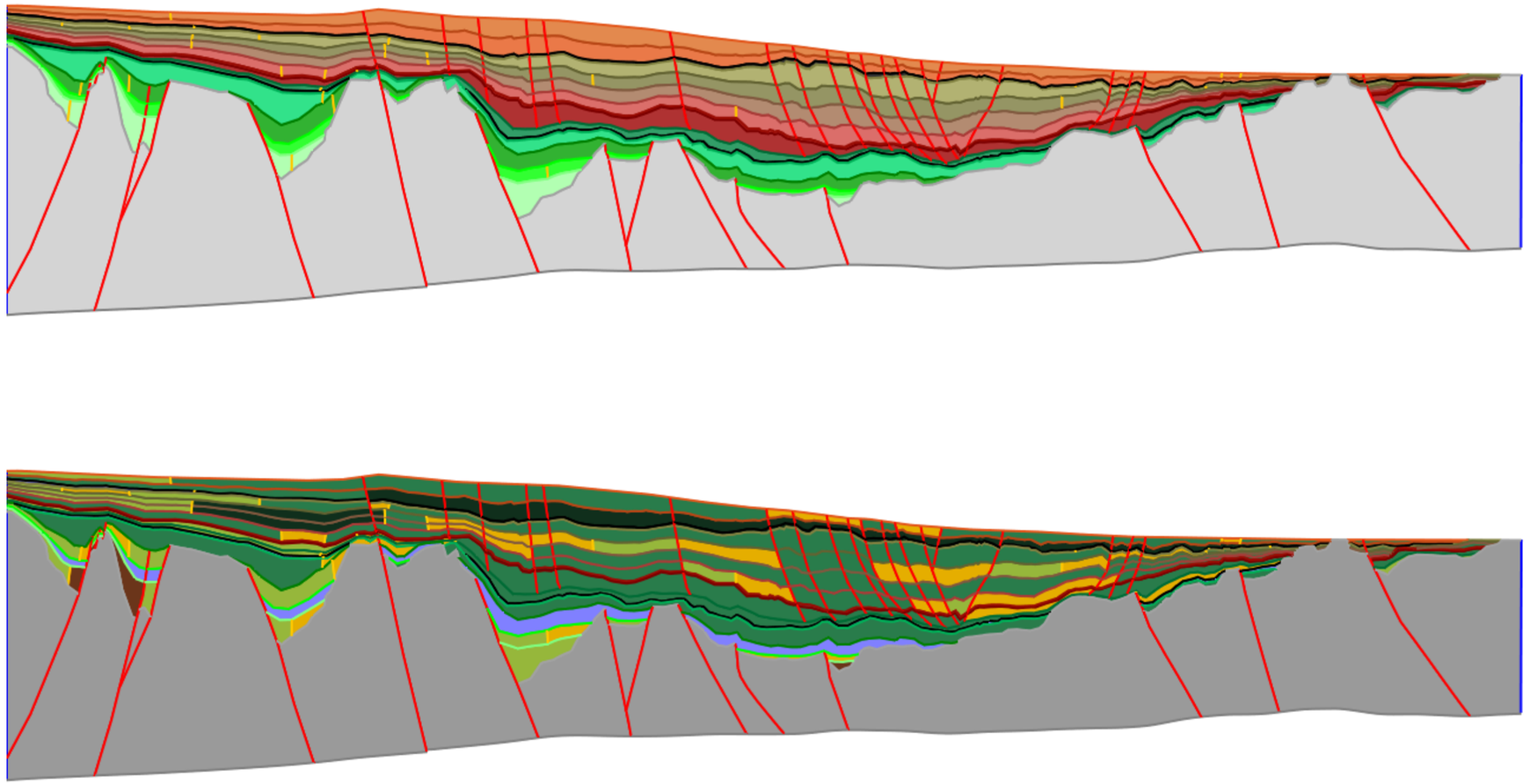
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

34 Ma



Vertical Exageration x4

0 25 50 km

Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
16	Eoc Sup	34
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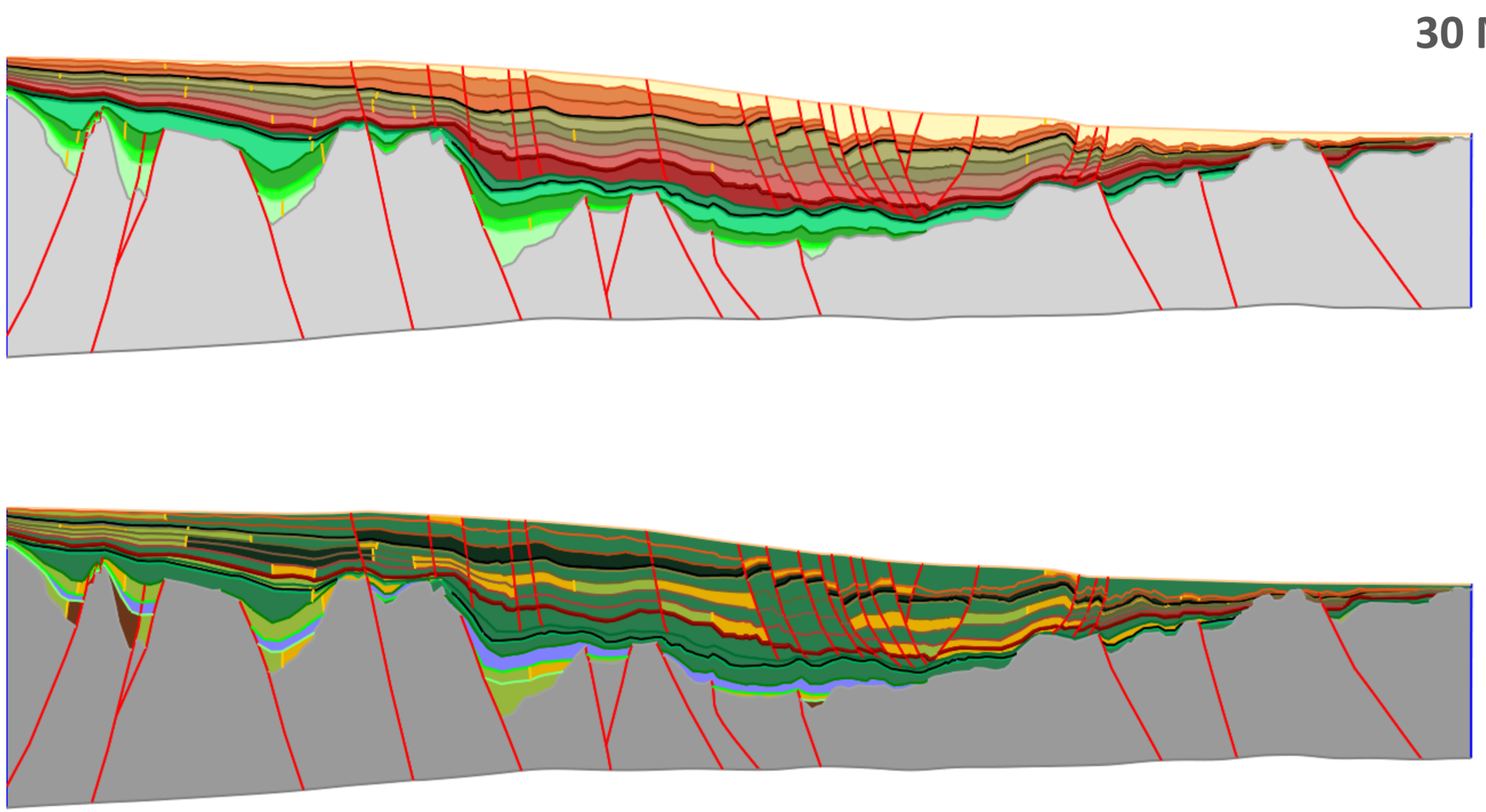
- Shale SR
- Upper Continental Crust

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
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22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
16	Eoc Sup	34
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14		44
13	Eoc Inf-Med	45
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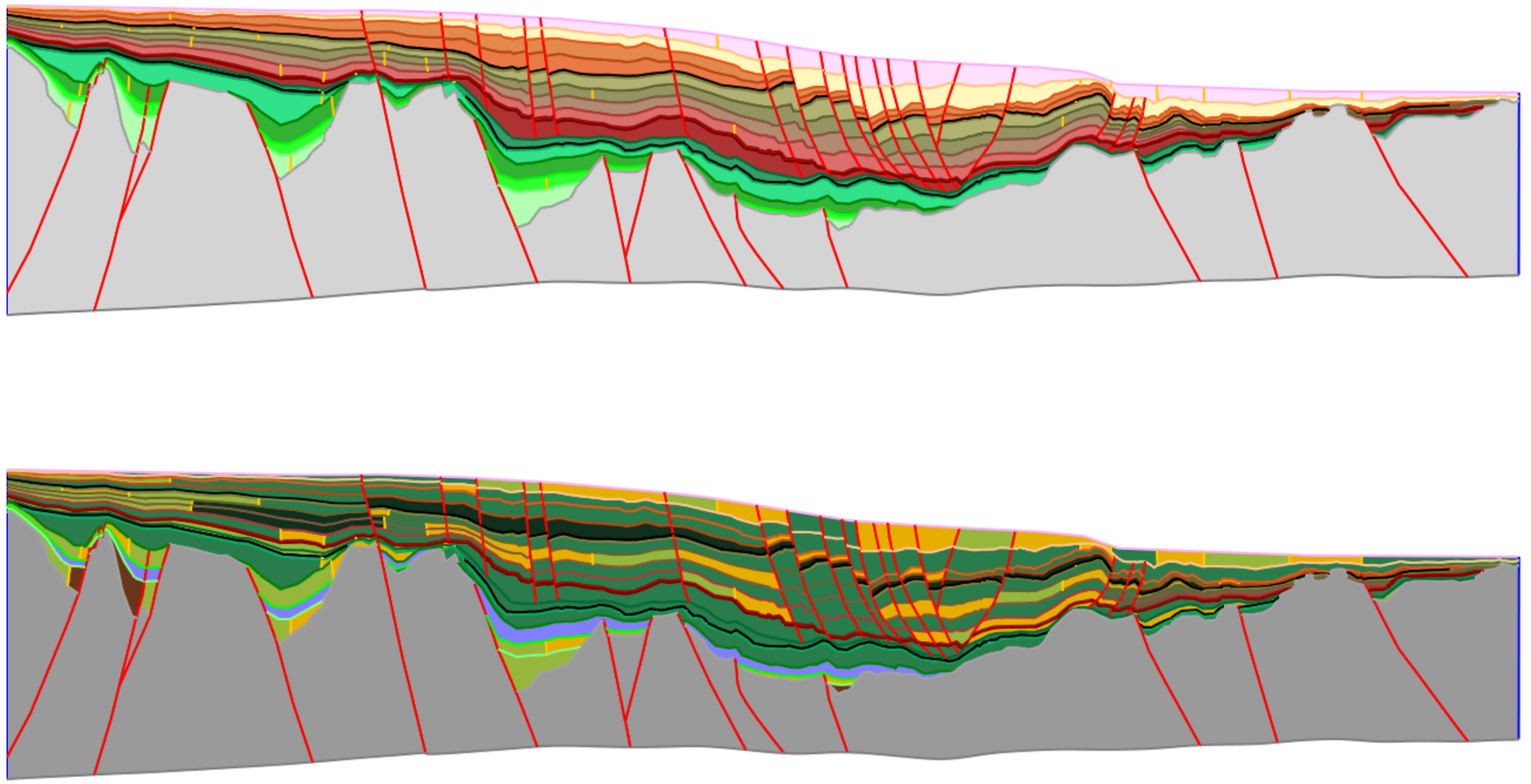
- Silt
- Shale
- Tight Shale
- Shale SR
- Upper Continental Crust

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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22		8
21	Mioc Inf	10
20		17
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- Shale
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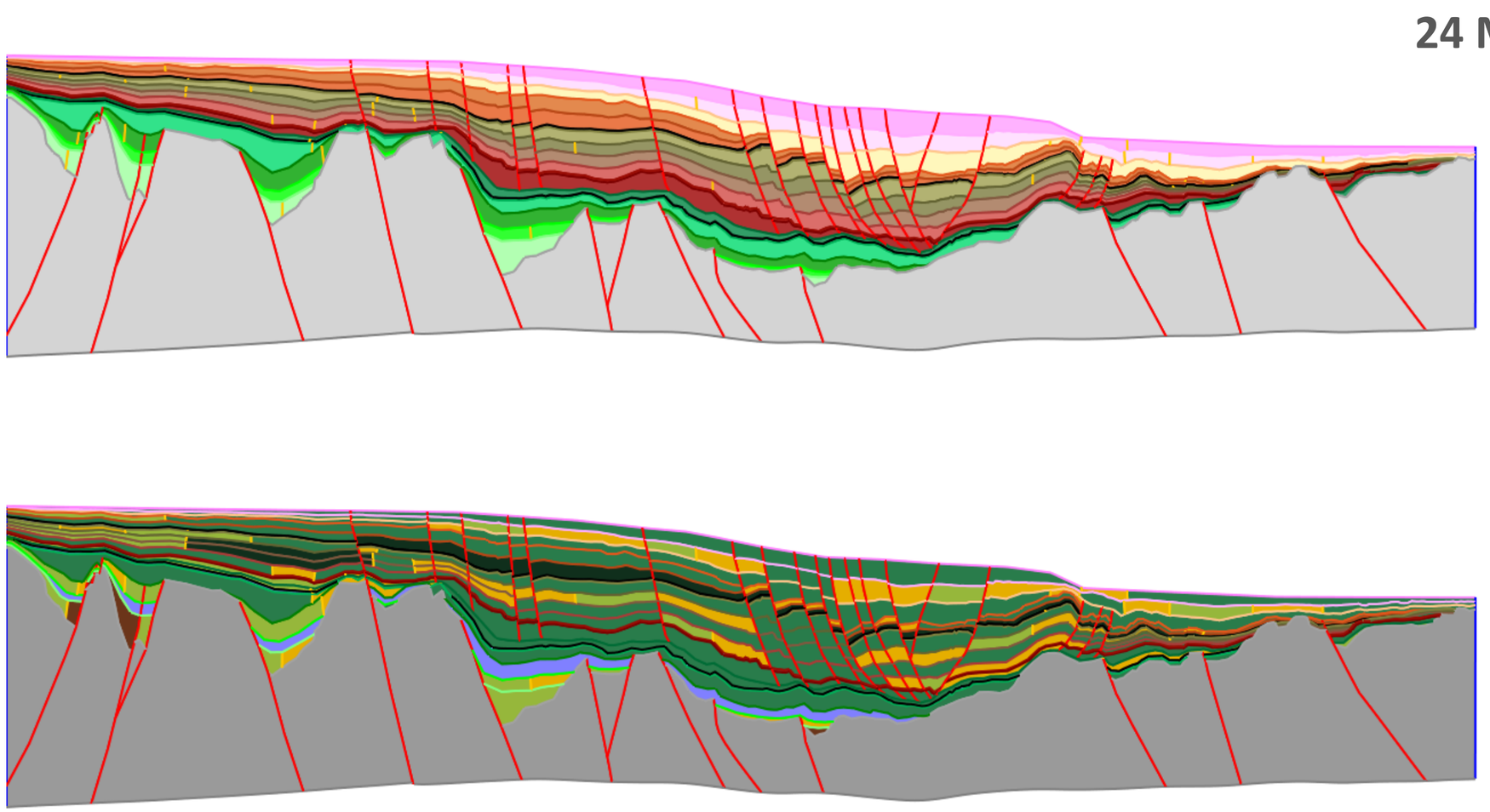
- Shale SR
- Upper Continental Crust

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
16	Eoc Sup	34
15		39
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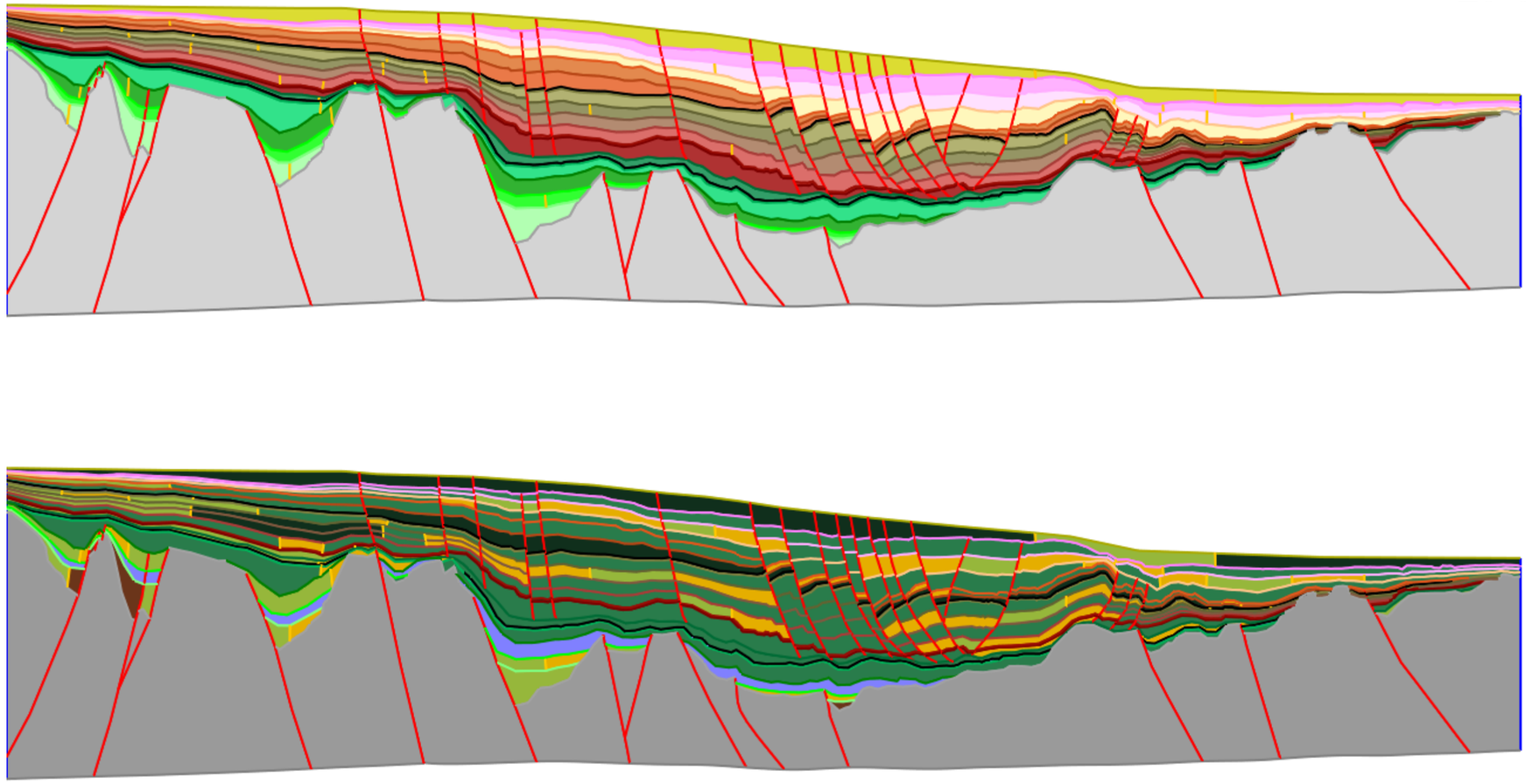
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

17 Ma



Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
16	Eoc Sup	34
15		39
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Sandstone
Silt
Shale
Tight Shale
Shale SR
Upper Continental Crust

Vertical Exageration x4

0 25 50 km

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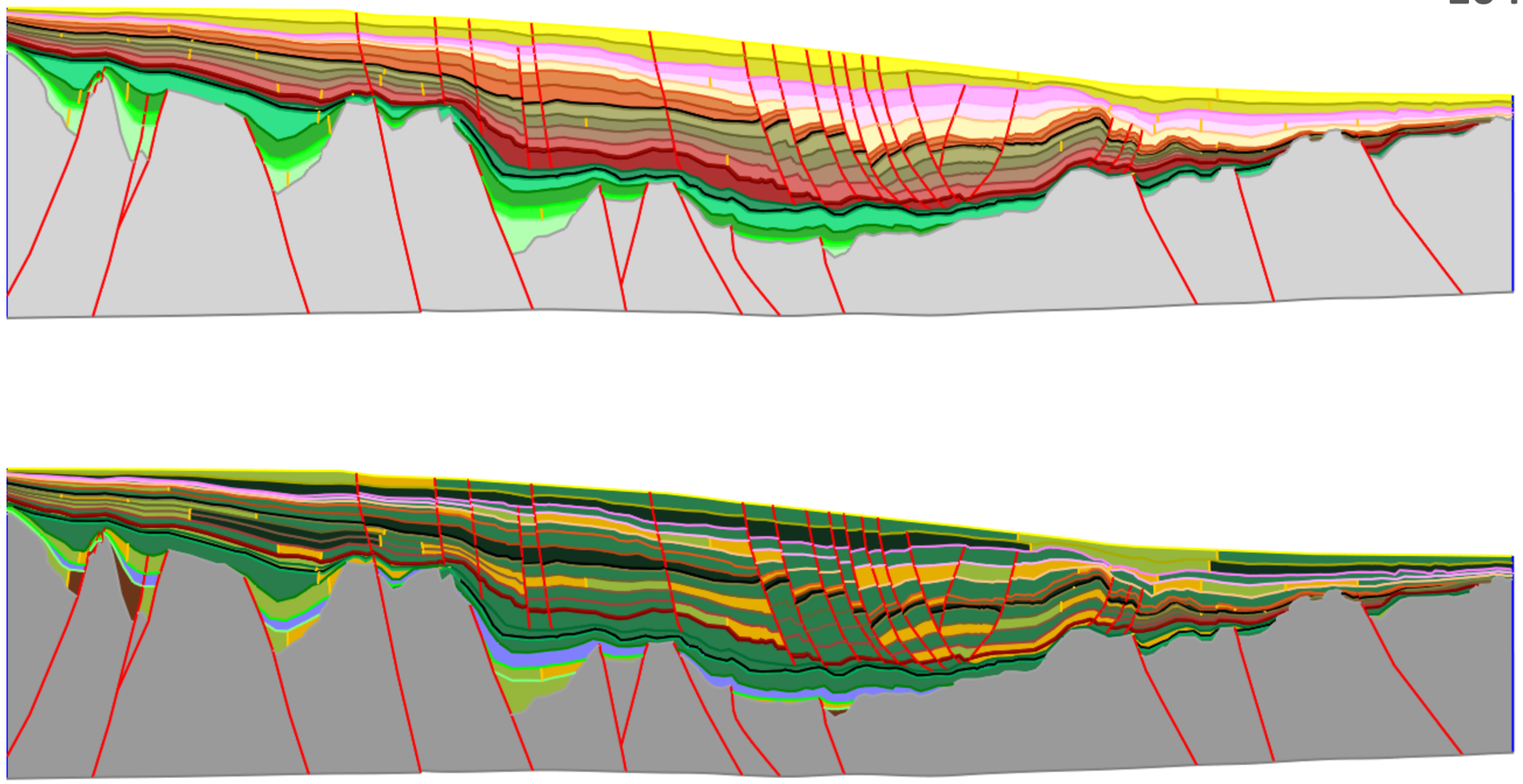
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
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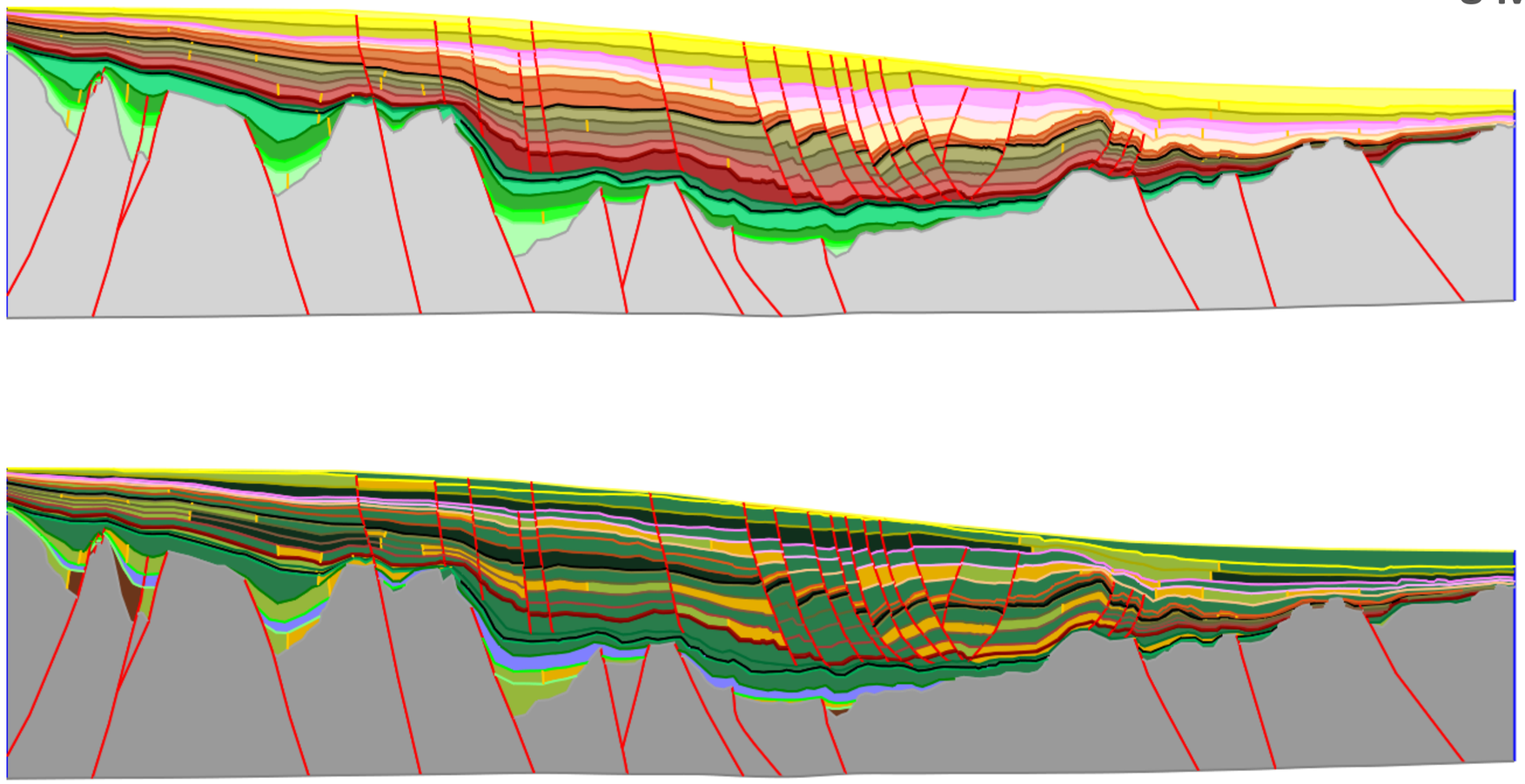
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
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23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
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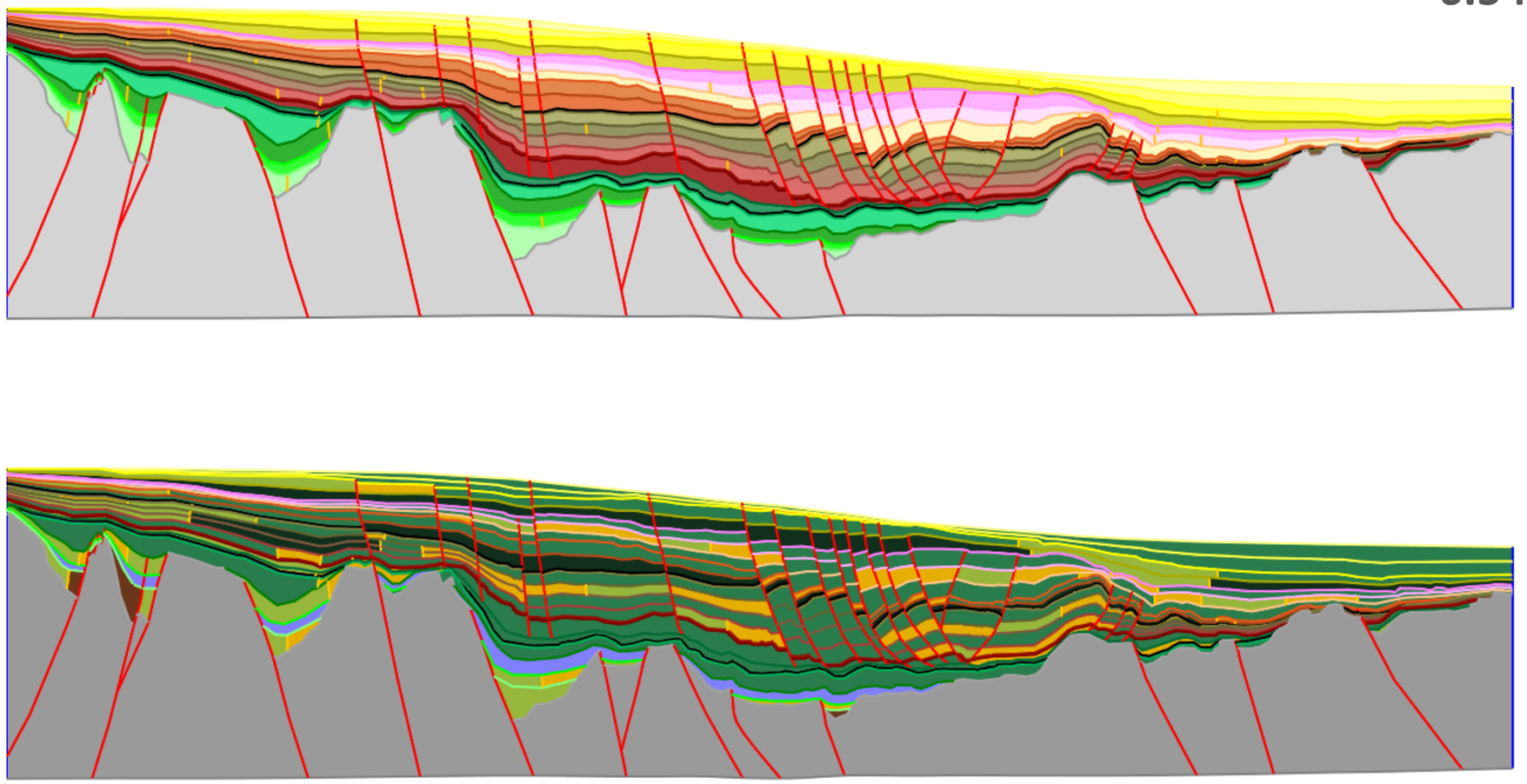
Kinematic Restoration

STRATIGRAPHY

LITHOLOGY

6.5 Ma



Layers	Period	Age (Ma)
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23	Mioc Med	6.5
22		8
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
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Sandstone
Silt
Shale
Tight Shale
Shale SR
Upper Continental Crust

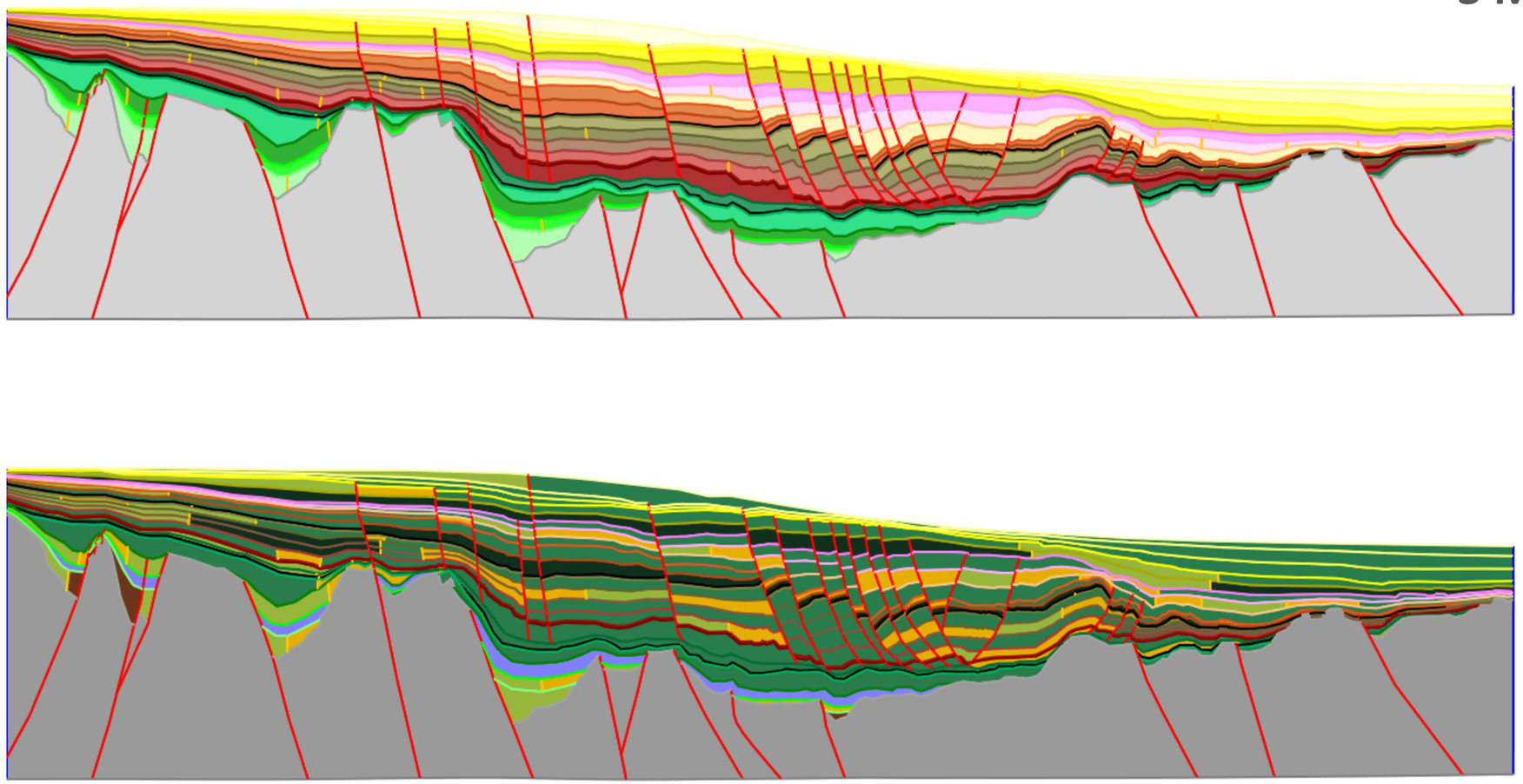
Vertical Exageration x4

0 25 50 km

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
23	Mioc Med	6.5
22		8
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
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4	KE	100
3		118
2		127
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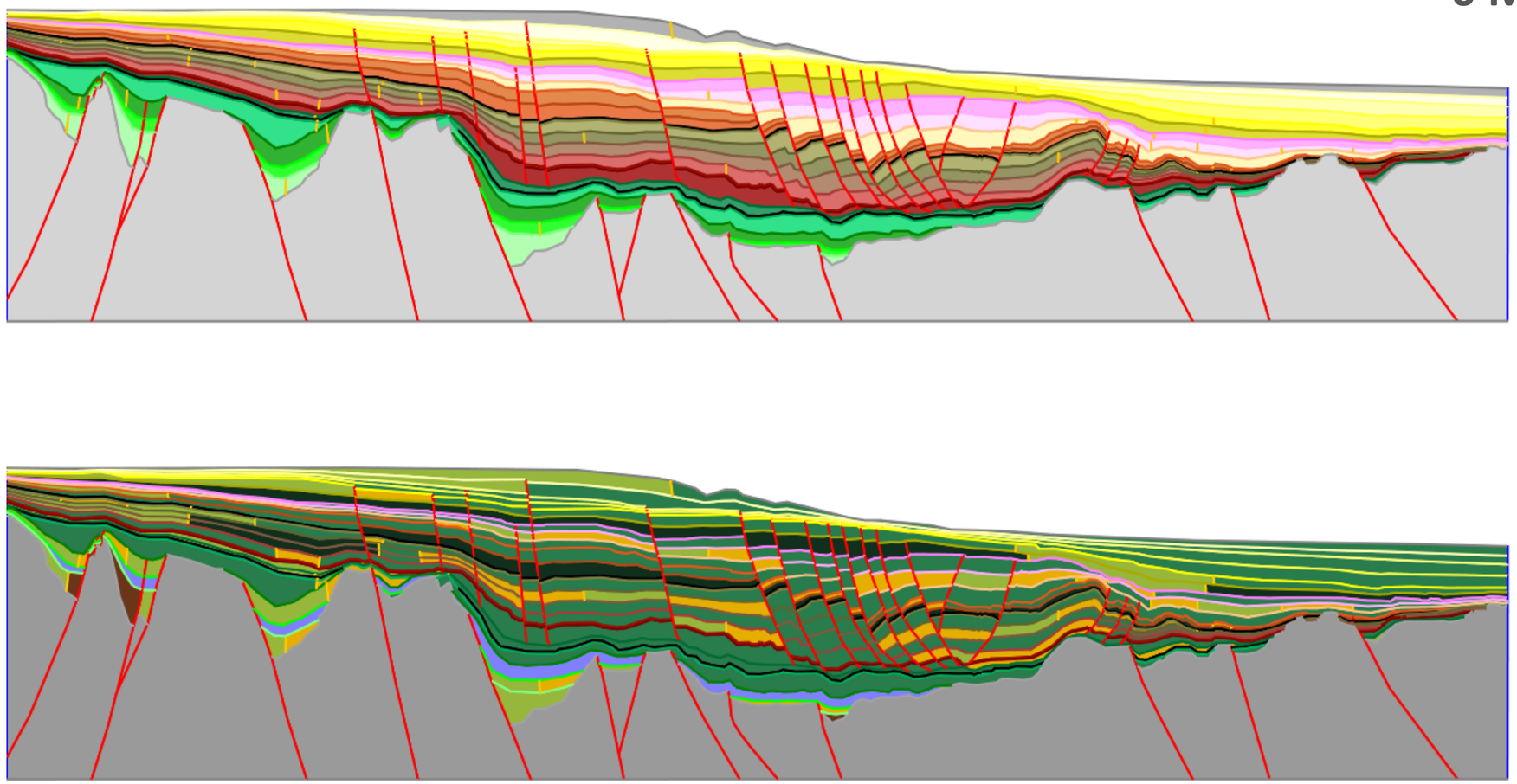
- Shale SR
- Upper Continental Crust

Kinematic Restoration

STRATIGRAPHY

LITHOLOGY



Layers	Period	Age (Ma)
25	Mioc Sup	0
24		3
23	Mioc Med	6.5
22		8
21	Mioc Inf	10
20		17
19	Olig	24
18		27
17		30
16	Eoc Sup	34
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Sandstone
Silt
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Tight Shale
Shale SR
Upper Continental Crust

Vertical Exageration x4

0 25 50 km

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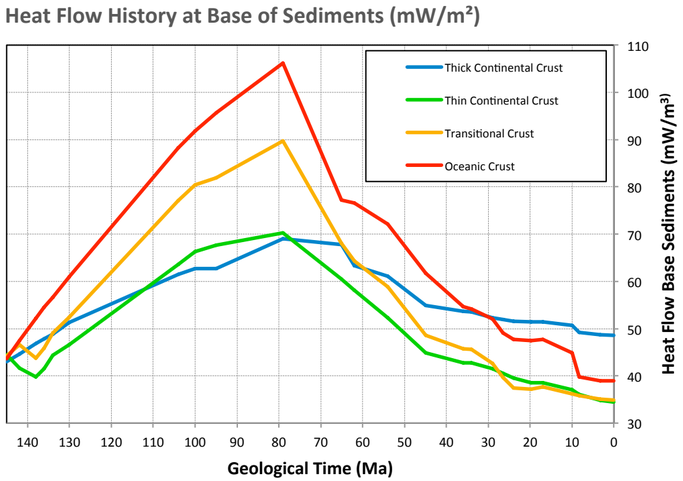
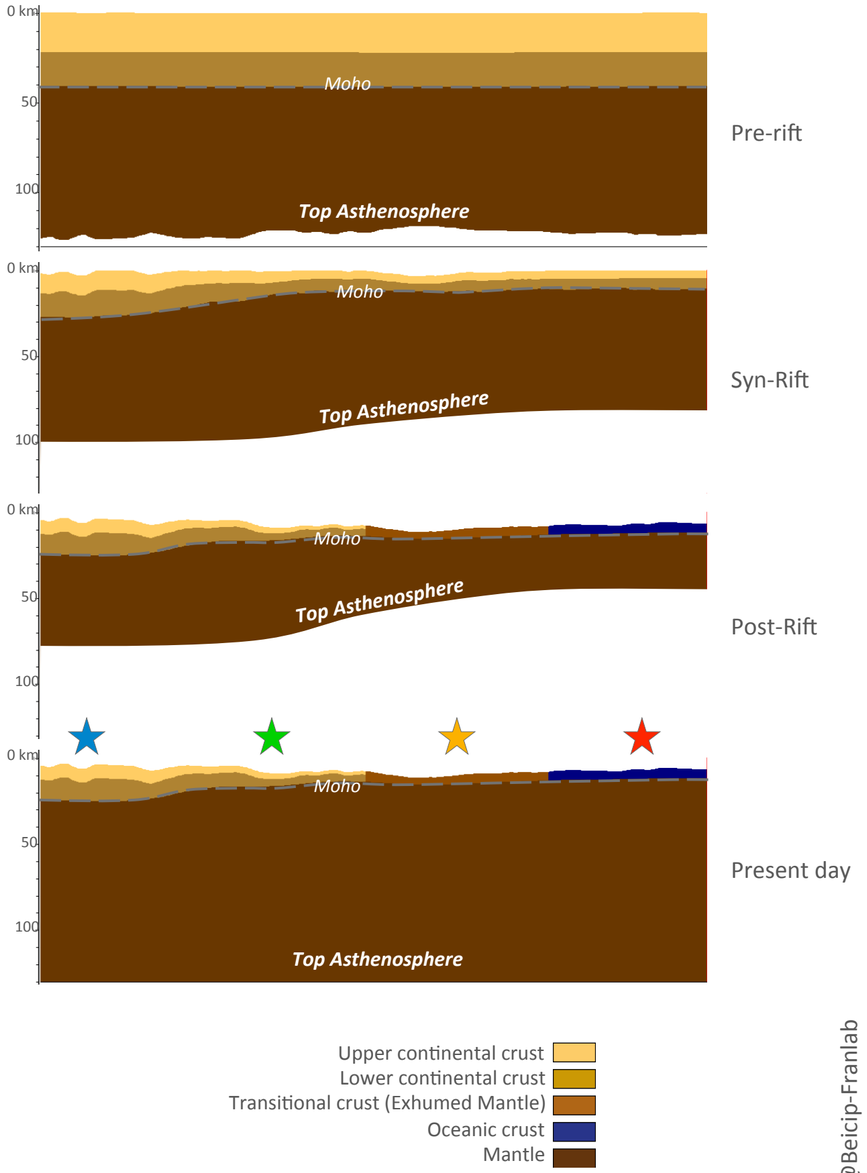
THERMAL EVOLUTION

Thermal **Rift**

- 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.

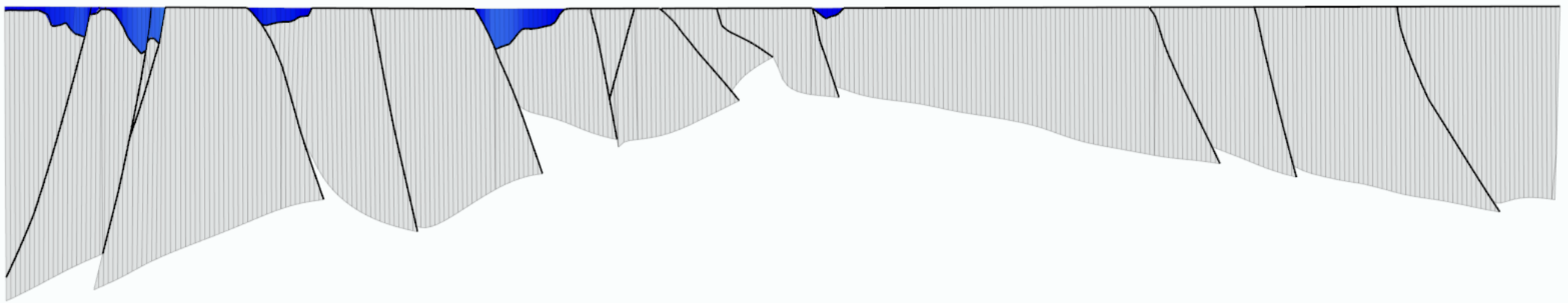


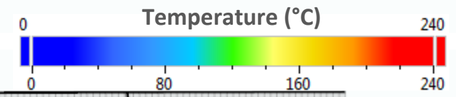


Thermal Regime

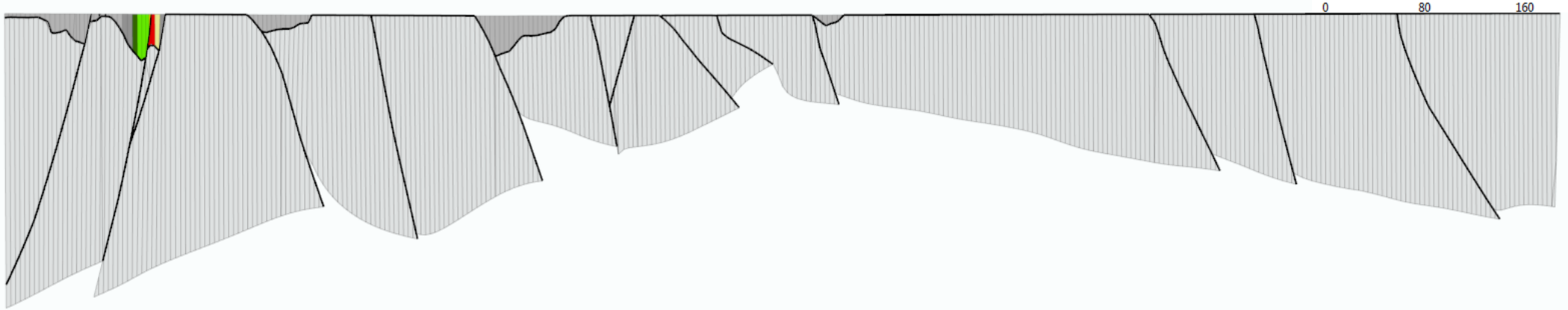
127 Ma

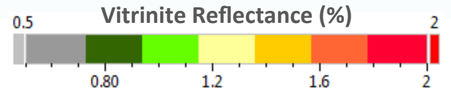
TEMPERATURE

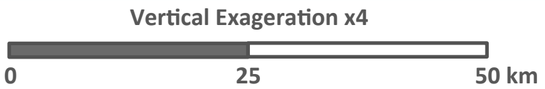




VITRINITE REFLECTANCE



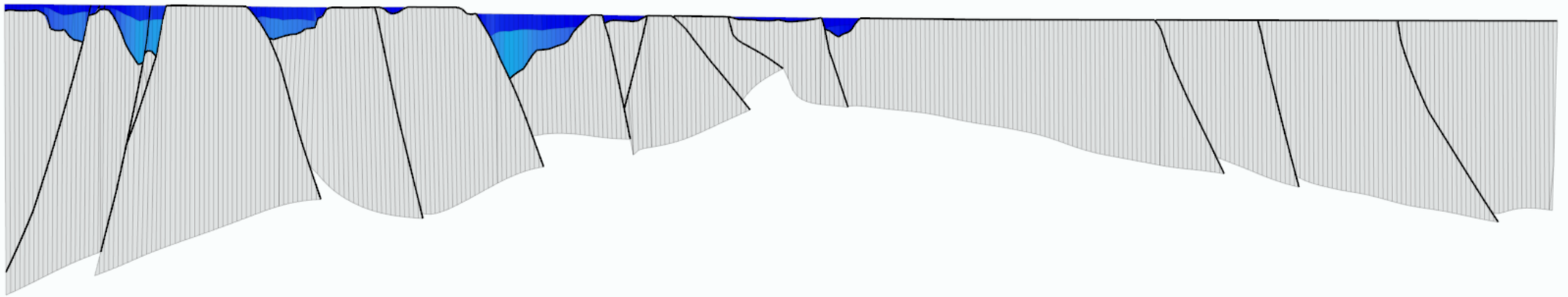




Thermal Regime

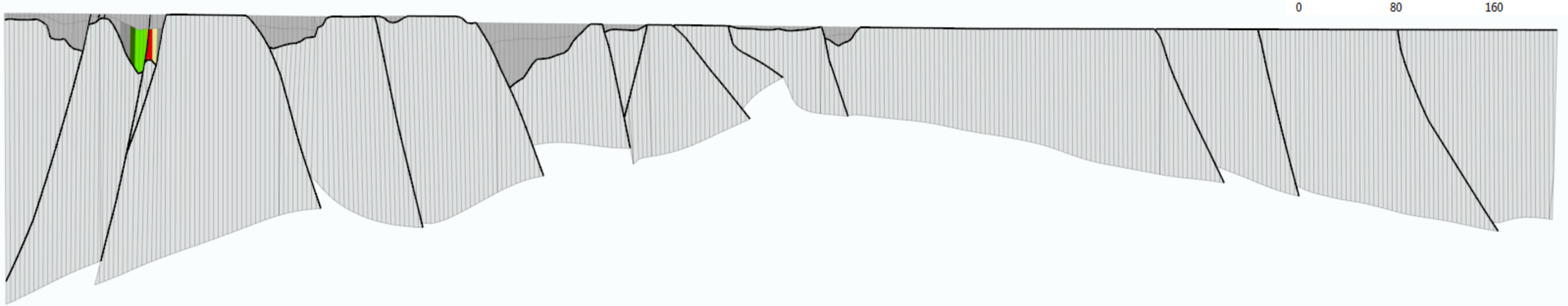
118 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



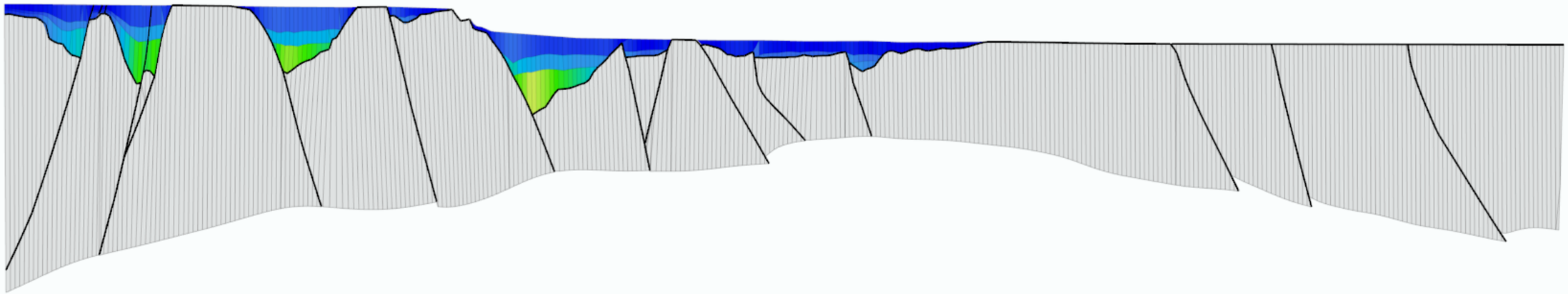
Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

Vertical Exageration x4
0 25 50 km

Thermal Regime

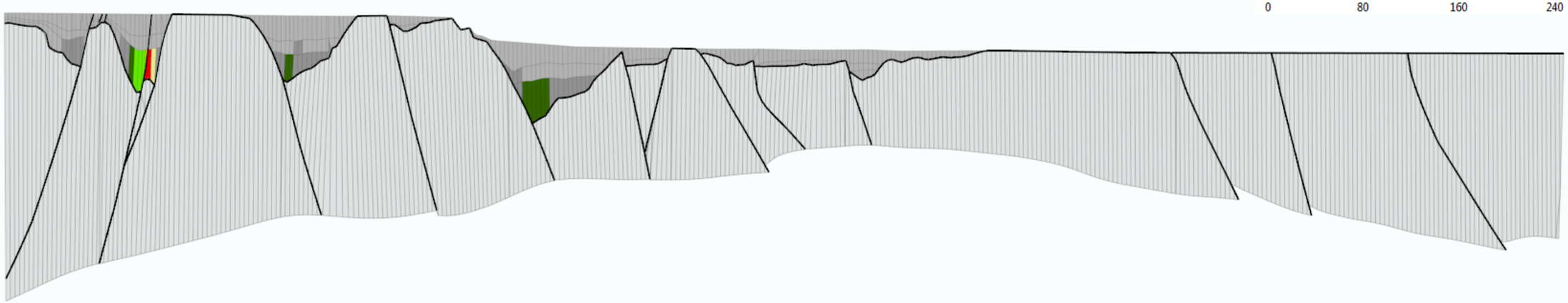
100 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



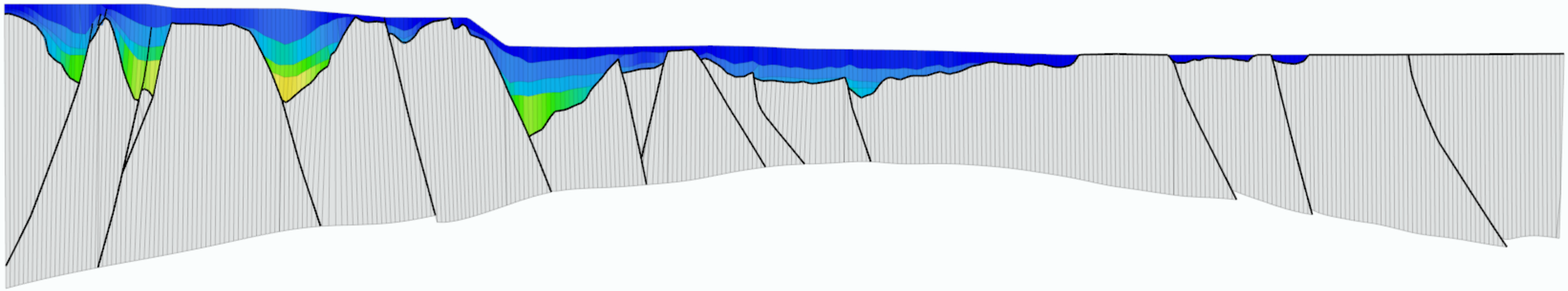
Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

Vertical Exageration x4
0 25 50 km

Thermal Regime

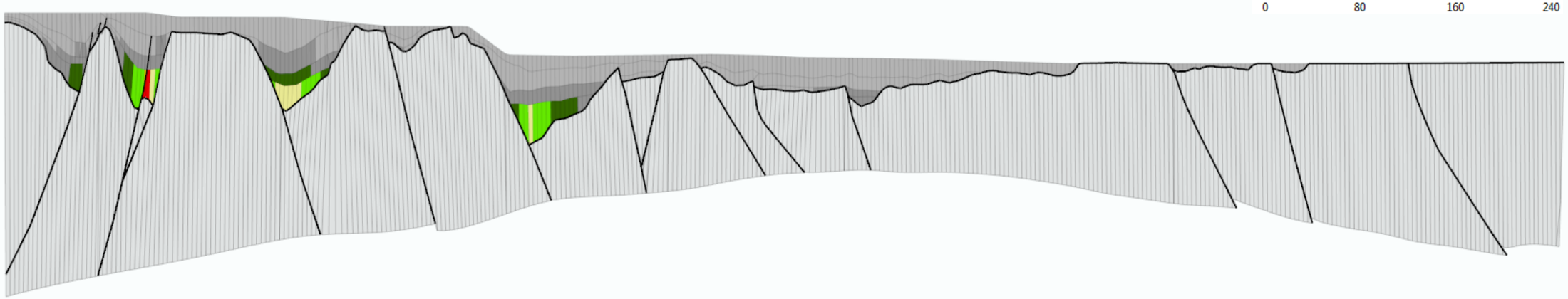
66 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



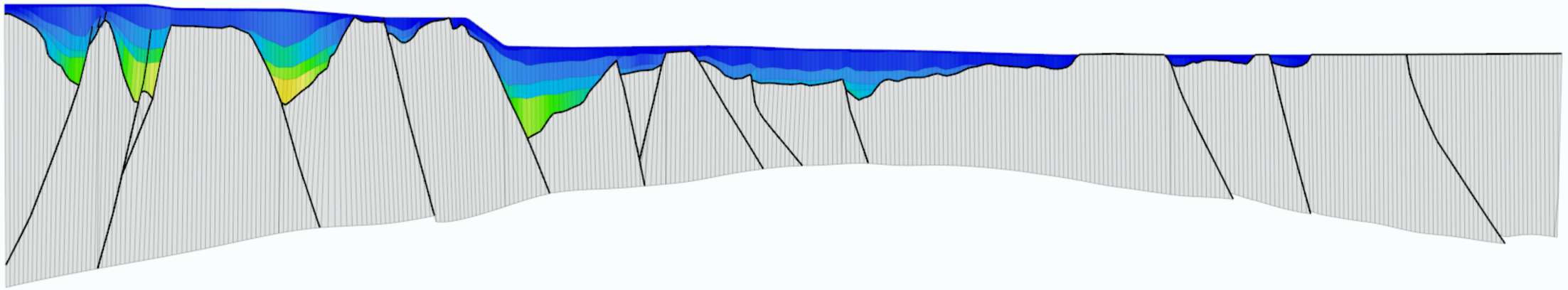
Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

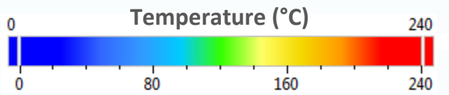
Vertical Exageration x4
0 25 50 km

Thermal Regime

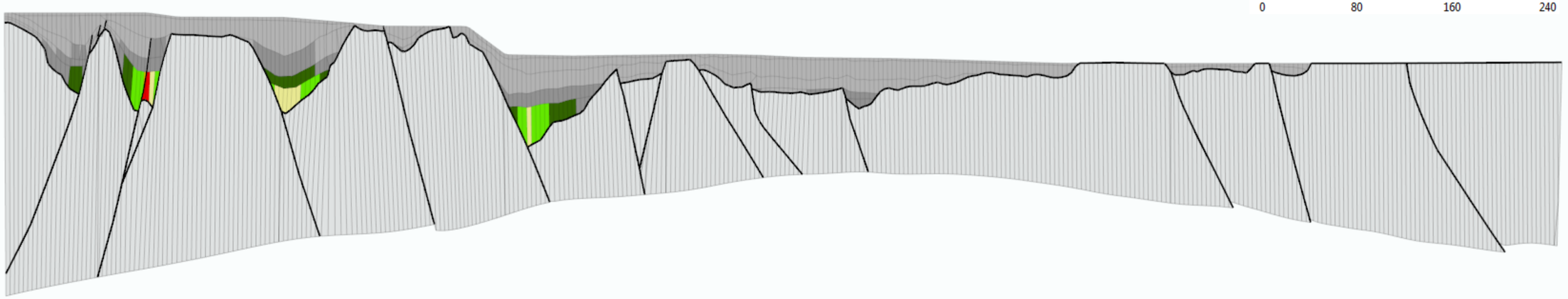
65 Ma

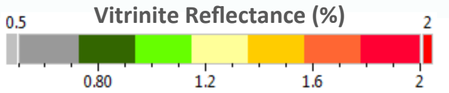
TEMPERATURE

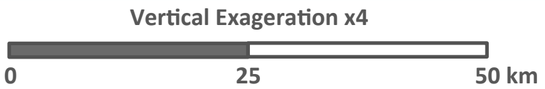




VITRINITE REFLECTANCE



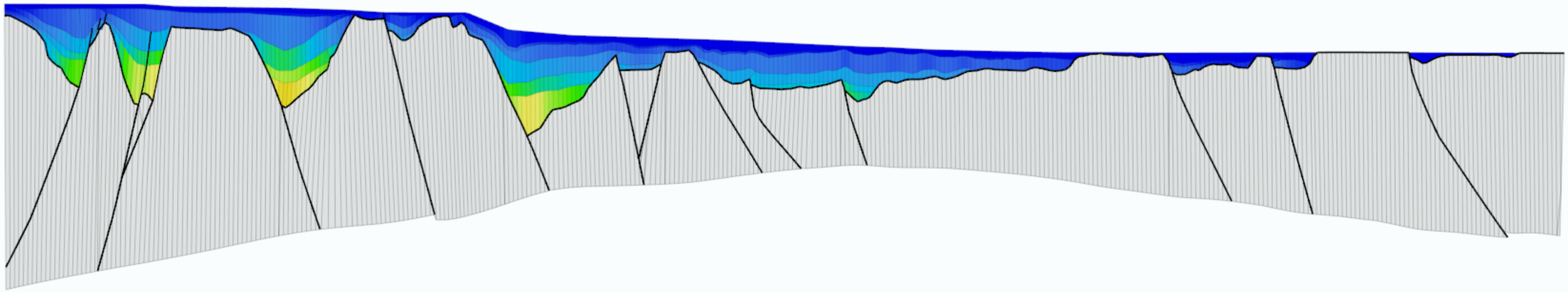




Thermal Regime

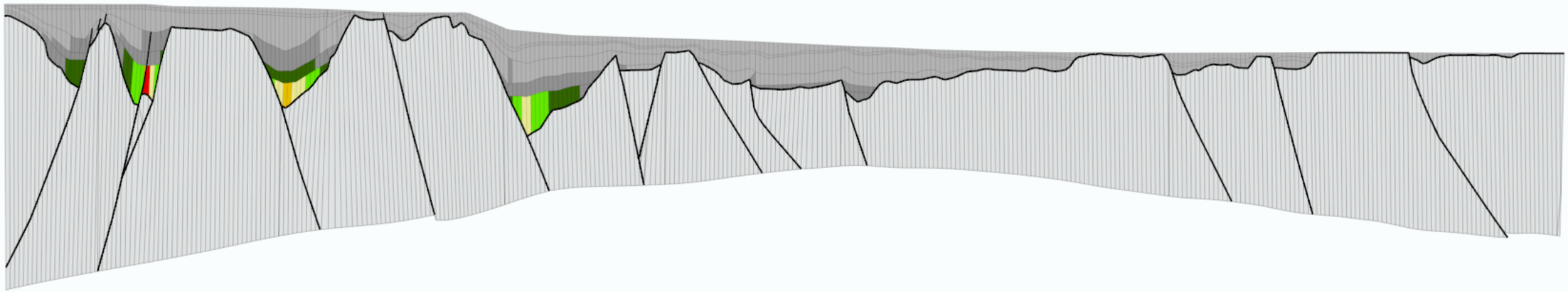
62 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



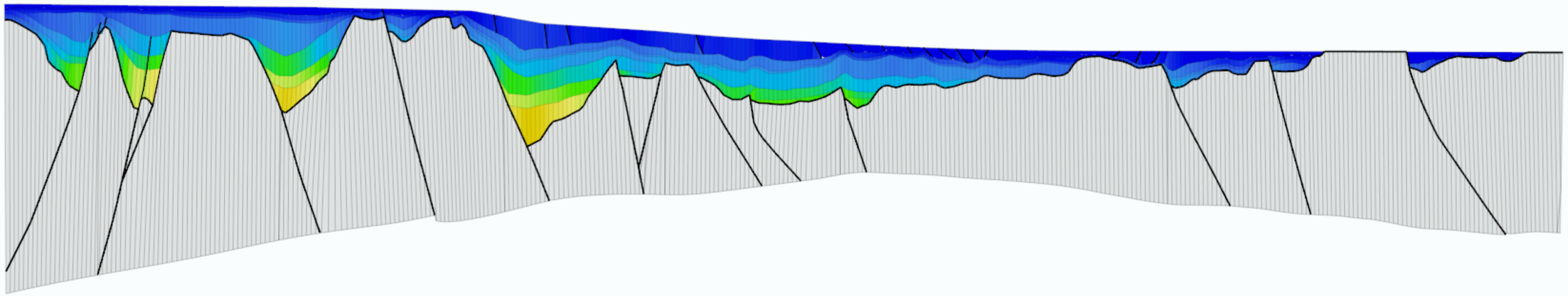
Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

Vertical Exageration x4
0 25 50 km

Thermal Regime

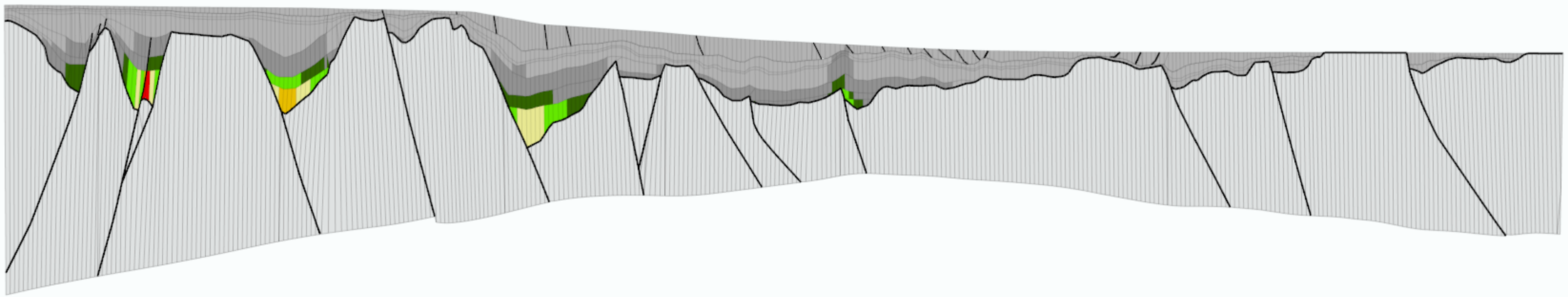
56 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



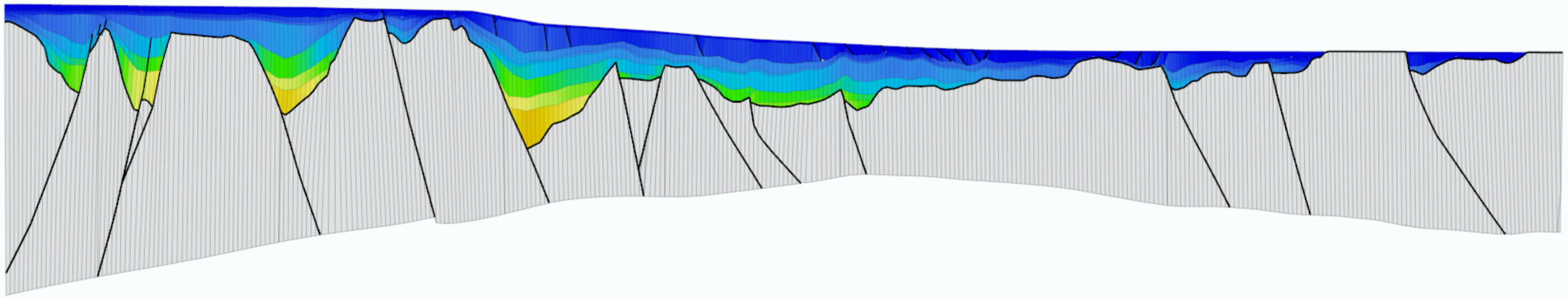
Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

Vertical Exageration x4
0 25 50 km

Thermal Regime

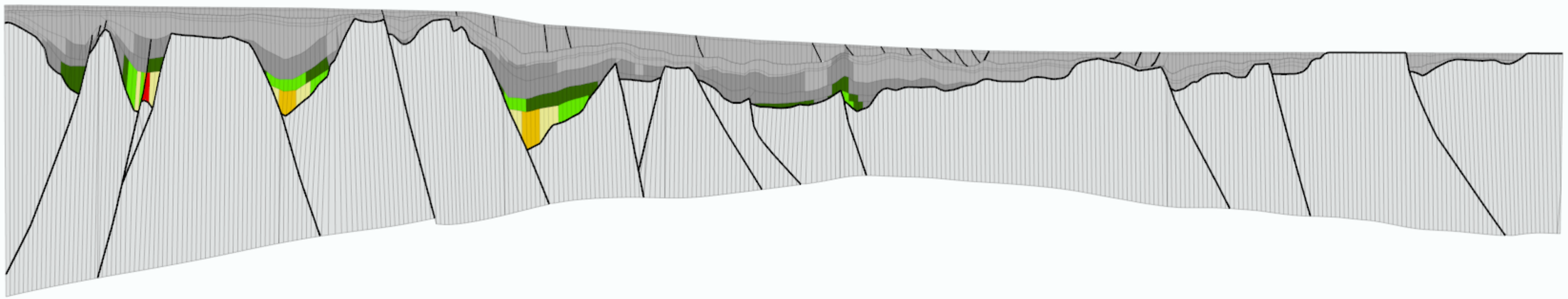
54 Ma

TEMPERATURE



Temperature (°C)
0 80 160 240

VITRINITE REFLECTANCE



Vitrinite Reflectance (%)
0.5 0.80 1.2 1.6 2

Vertical Exageration x4
0 25 50 km