Systematic Evaluation of Unconventional Resource Plays Using Petroleum System Modeling Combined with Play Chance Mapping*

Ian Bryant[1]

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Abstract

Petroleum system modeling has long been used to model generation, migration and entrapment of yet-to-be-discovered hydrocarbons in conventional plays. The same software has been modified to give improved prediction of the hydrocarbons remaining in the source rock that constitute unconventional plays. This methodology provides predictions of secondary porosity, fluid type, pressure, adsorbed vs. free gas and geomechanical properties. Play chance mapping of these parameters, combined with other elements of the play, may be used to identify sweet spots early in the life of an unconventional play prior to extensive drilling.

Selected References

Behar, F., M. Vandenbroucke, Y. Tang, F. Marquis, and J. Espitale, 1997, Thermal cracking of kerogen in open and closed systems; determination of kinetic parameters and stoichiometric coefficients for oil and gas generation: Organiz Geochemistry, v. 26/5-6, p. 321-339.

Decker, P.L., 2011, Source-reservoired oil resources, Alaskan North Slope: Alaska Department of Natural Resources, Division of Oil and Gas, 52 p.

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Neber, A., S. Cox, T. Levy, O. Schenk, N. Tessen, B. Wygrata, and I. Bryant, 2012, Systematic Evaluation of Unconventional Resource Plays Using a New Play-Based Exploration Methodology: SPE 158571, 15 p.

Peters, K.E., K.J. Bird, J.E. Zumberge, L.S. Ramos, and D.L. Gautier, 2006, Use of a new Circum-Arctic chemometric model to study mixtures of Shublik and younger oils in Northern Alaska: GSA Abstracts with Programs, v. 38/5, p. 71.

Website

Bailey, A., 2012, Great Bear (Petroleum) wants to speed up shale program; Company's North Slope test well boosts confidence that change of plan needed: Anchorage Daily News, September 22, 2012. Web accessed 26 March 2013. http://www.adn.com/2012/09/22/2636242/great-bear-wants-to-speed-up-shale.html#storylink=cpy

Systematic evaluation of unconventional resource plays using petroleum system modeling combined with play chance mapping

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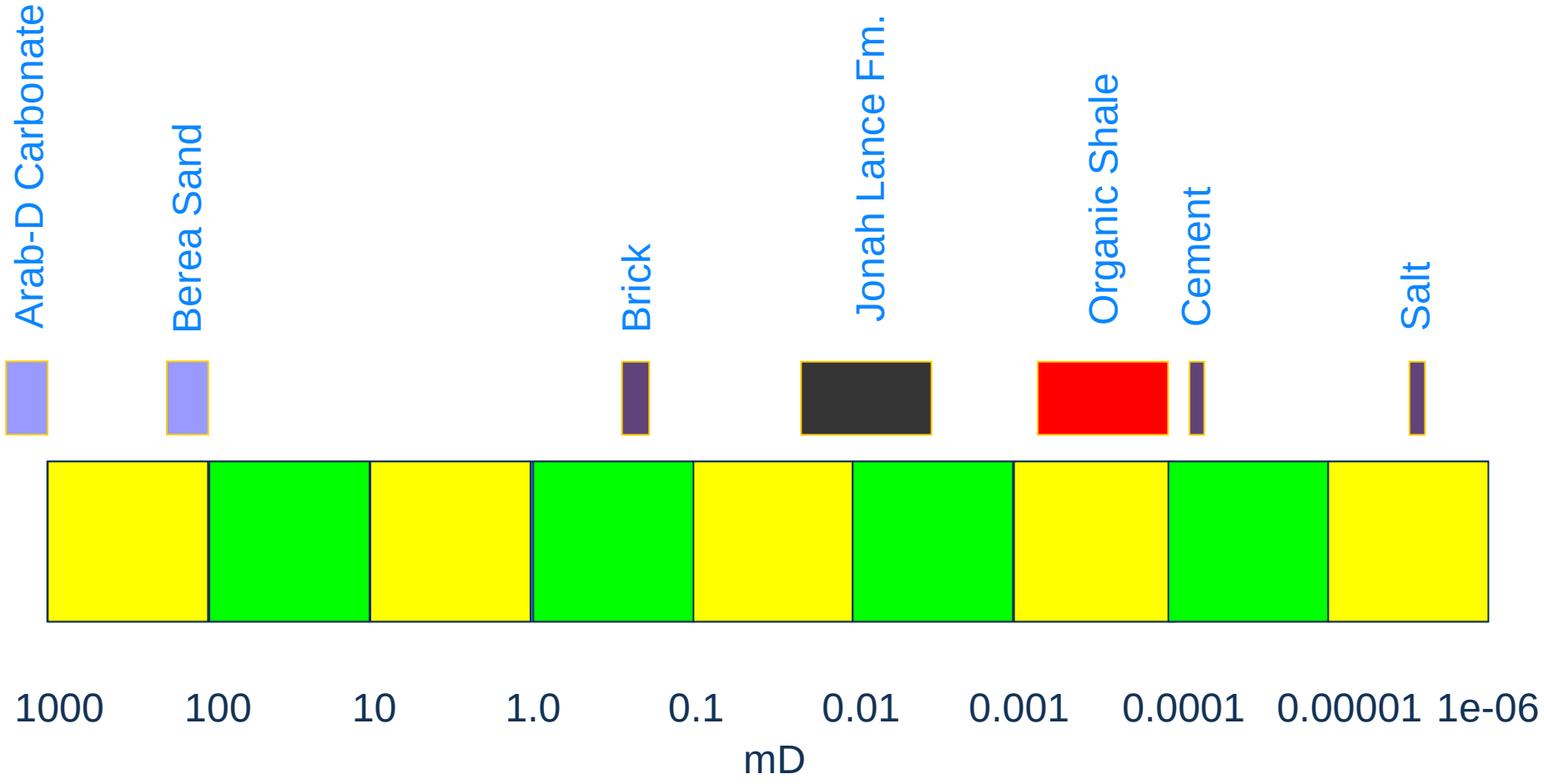
AAPG GTW, Houston, 2012

Schlumberger

Agenda

- Introduction
  - Understanding geology **and** technology is key
- Petroleum System Modeling
- Play chance mapping
- Case Studies - getting the right acreage early in play
  - Data-poor example: Haynesville gas play
  - Data-rich example: Alaska oil play
- Conclusions

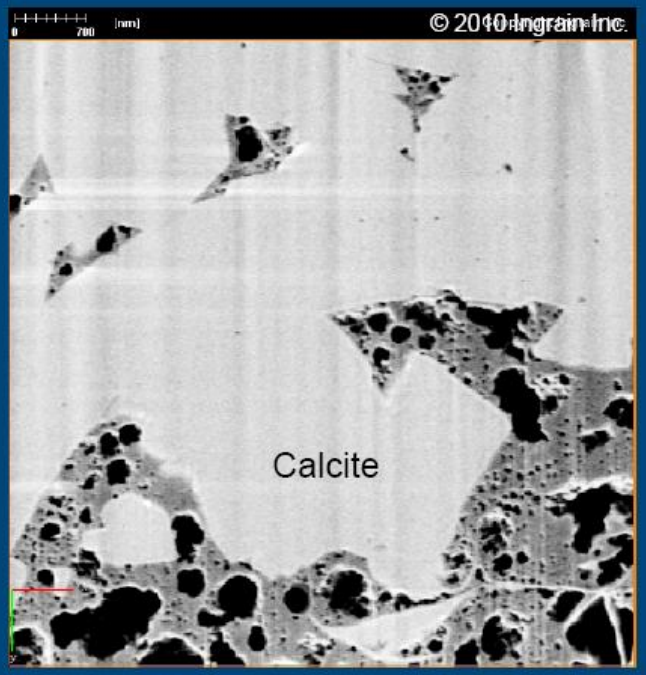
Shale in Perspective: Permeability



Porosity in Kerogen

Nano 3

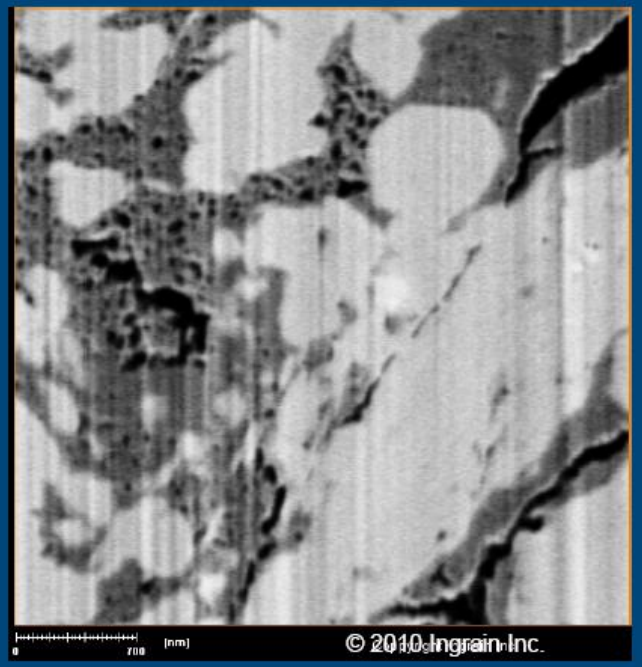
Shale 3: Gas/oil window. Producer



Kerogen= 10.61%
Pore= 8.24%
Connected porosity= 0 %
K= 0

From nano-volume:
Pore + Kerogen: 5%

Shale 4: Oil window. Producer



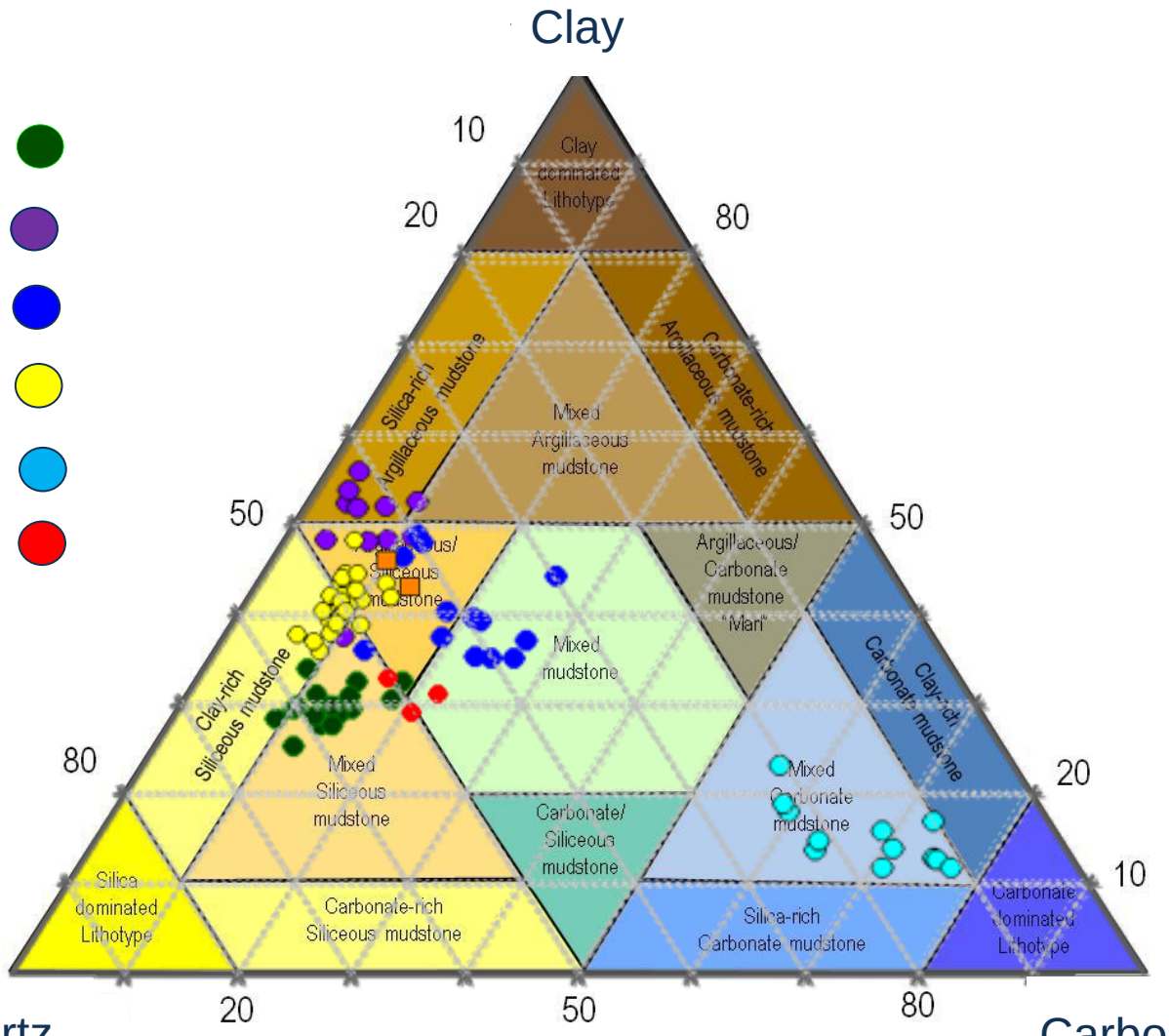
Kerogen: 24%
Pore: 5%
Connected porosity_Z= 1.6 %
Kz= 0.002 mD

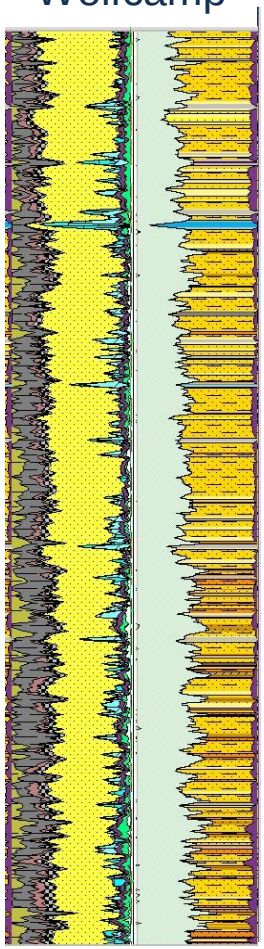
From nano-volume:
Pore + Kerogen: 11.2%

Diaz., 2010

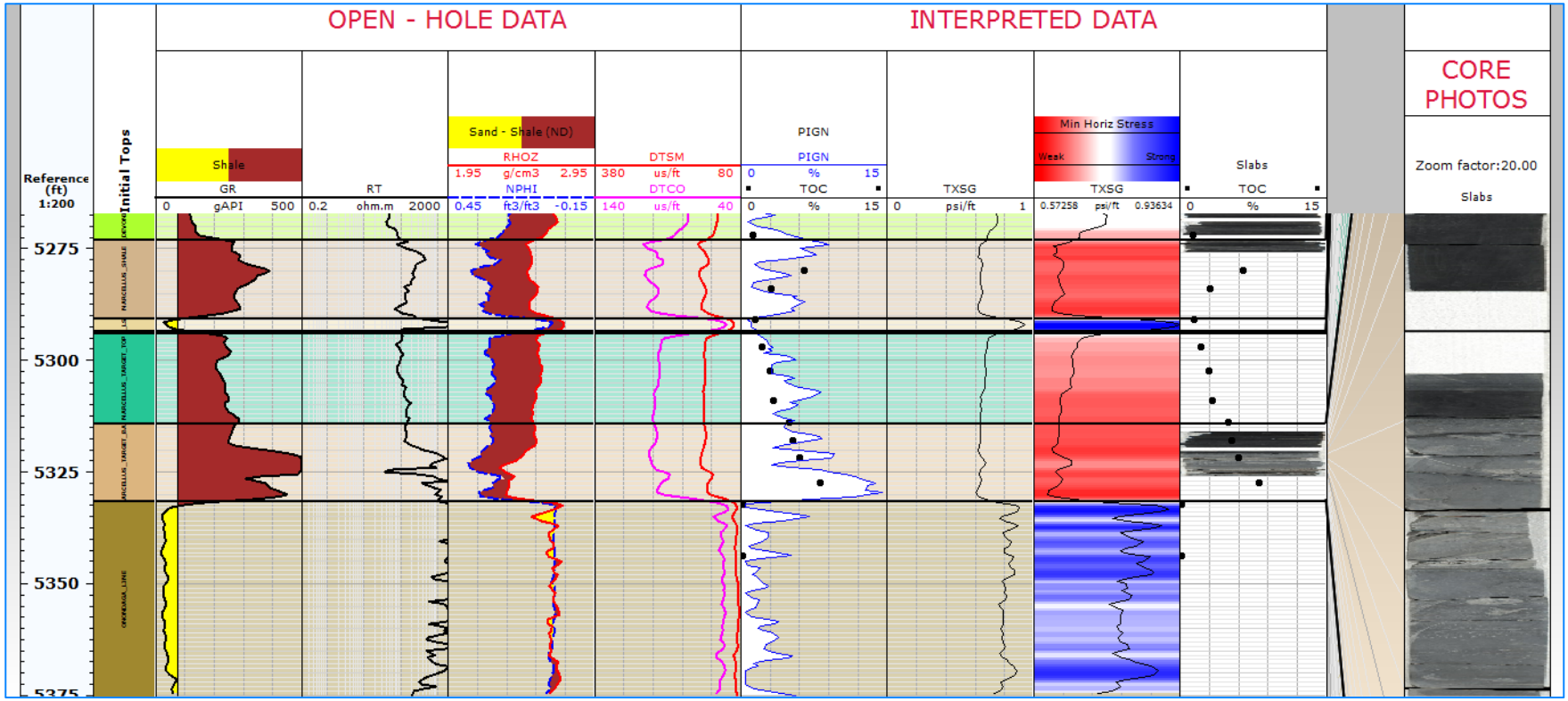
Shale Plays: Variations in Bulk Mineralogy

Barnett
Marcellus
Haynesville
Fayetteville
Eagle Ford
Wolfcamp



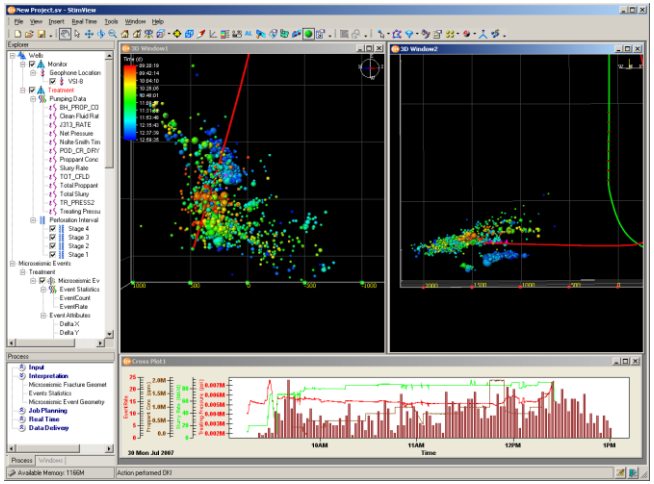


TOC and In Situ Stress - Marcellus Example



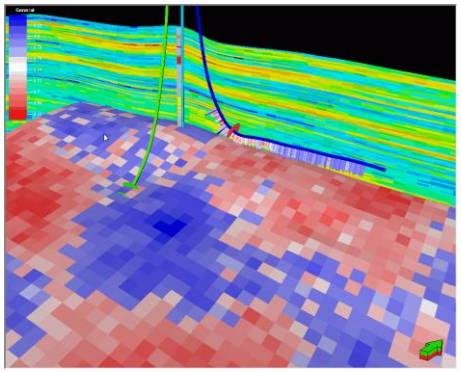
Keys for Success in Unconventional Reservoirs

Understand the geology



Understand the technology

Use models to leverage the appropriate technology and create value



Keys for Exploration Economic Success

Rich resource in place

- Maturity of source rocks
  - Oil, wet gas or dry gas?
- Porous and permeable

Good quality reservoir filled with the desired hydrocarbon fluids

Economically recoverable with current technology

- Drillablity
- Fracability
  - Geomechanical properties
  - Stress distribution

Ability to create high quality completions at the right price

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Role of Petroleum System Modeling

	Property	Log	Core	Petroleum System Modeling
	Matrix porosity	Yes	Yes	Yes
	Fractures	Yes	Yes	No
Reservoir Quality	Matrix permeability	Yes	Yes	Yes
	Fluid type	Yes	Yes	Yes
	Pore pressure	No	No	Yes
	Organic content	Yes	Yes	No
	Mineralogy	Yes	Yes	No
Completion Quality	Rock strength	Yes	Yes	Yes
	In situ stress	Yes	No	Yes

Modified from: Moumen Bouhel & Bryant, 2012. SPE 152455

PetroMod Viewer 3D - v11 SP 1 Windows 32-bit

File Object Overlay Tools Options Windows Help

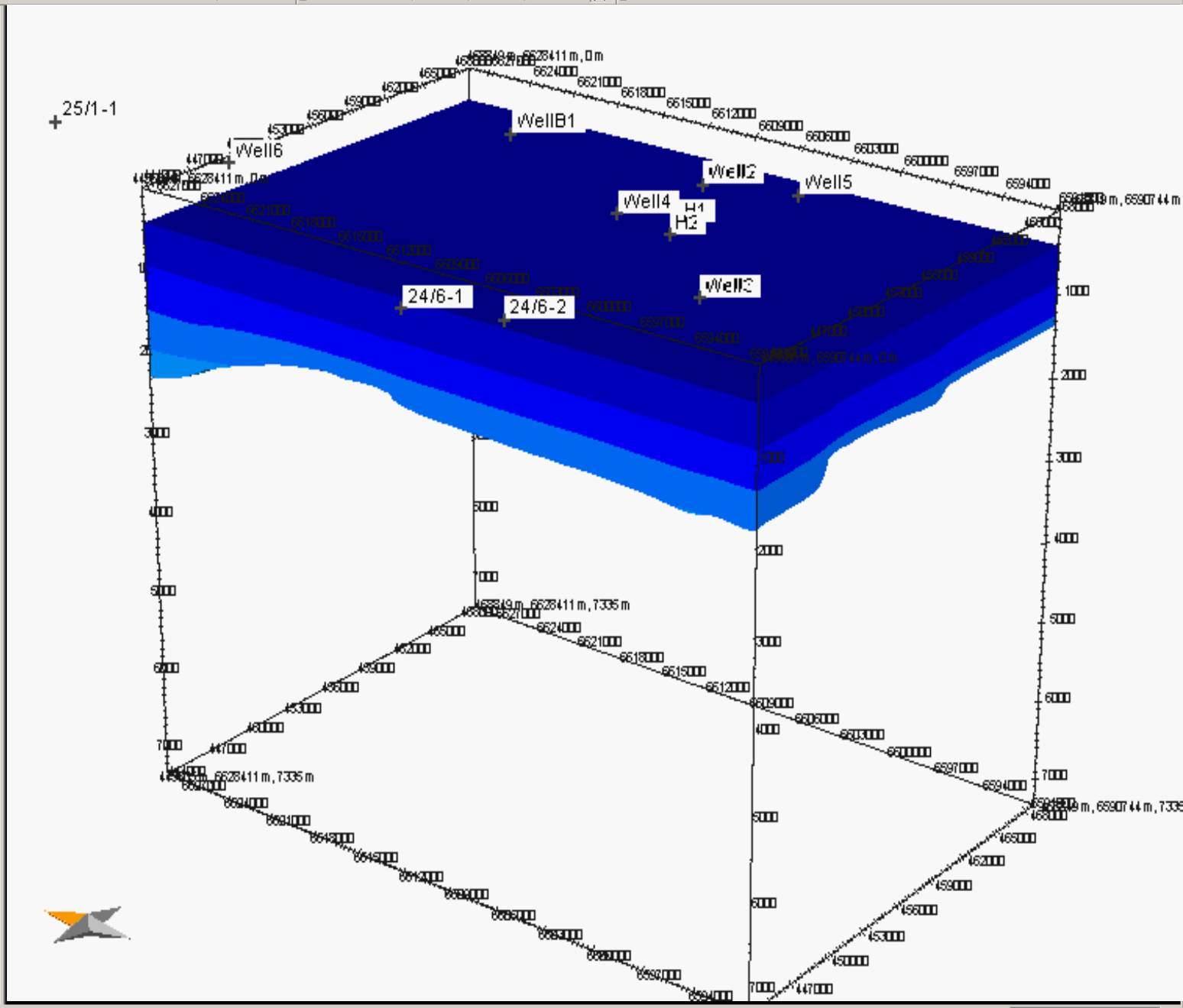
Browser

0.0 Ma - Piacenian_Strata

- Annotations
- PX_Exercise_3
  - Legends
  - Overlays
  - Horizons
  - Layers
  - Faults
  - Reservoirs
  - Risk
  - Vectors
  - Saturations
  - Culture
  - Initial Faults
  - Labels
  - Wells
  - SEG Y Seismic

Info

PX_Exercise_3



PX_Exercise_3; No overlay

Conventional vs. Unconventional Resource Petroleum Systems Modeling

Conventional

- HC has migrated to reservoir
- Secondary cracking of oil to gas in reservoir is not important
- Porosity is modeled in reservoir
- Model free gas in reservoir

Unconventional

- HC is still in source rock
- Secondary cracking of oil to gas is important
- Conversion of kerogen creates porosity in source rock
- Adsorption is an important parameter (vs. free gas)

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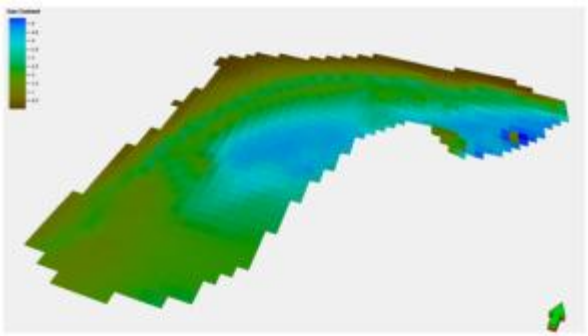
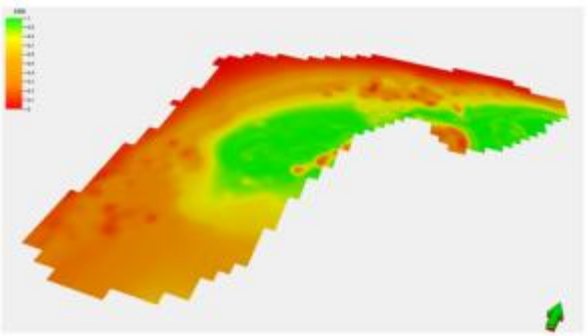
Play Chance Mapping

- Transform maps of physical properties to chance of success maps for each of the elements of exploration risk
- Combine maps to map overall chance of success for the play and define “sweet spots”



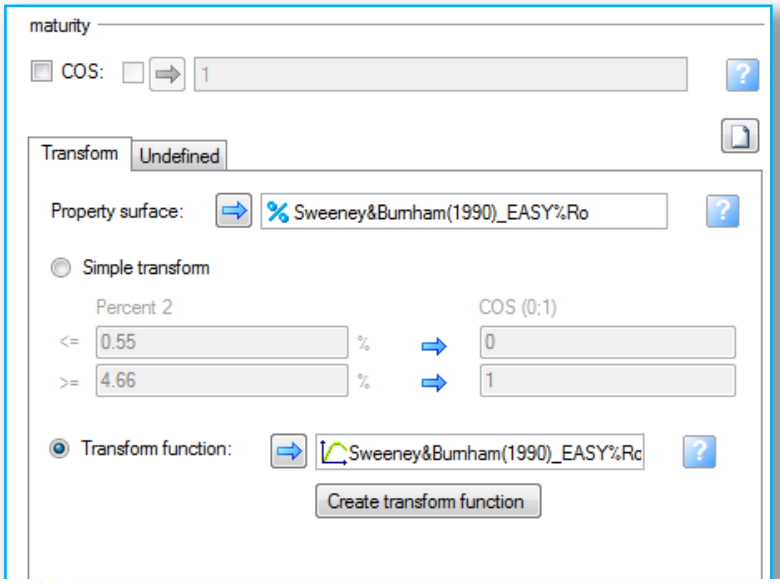
Gas in Place
scft/ton

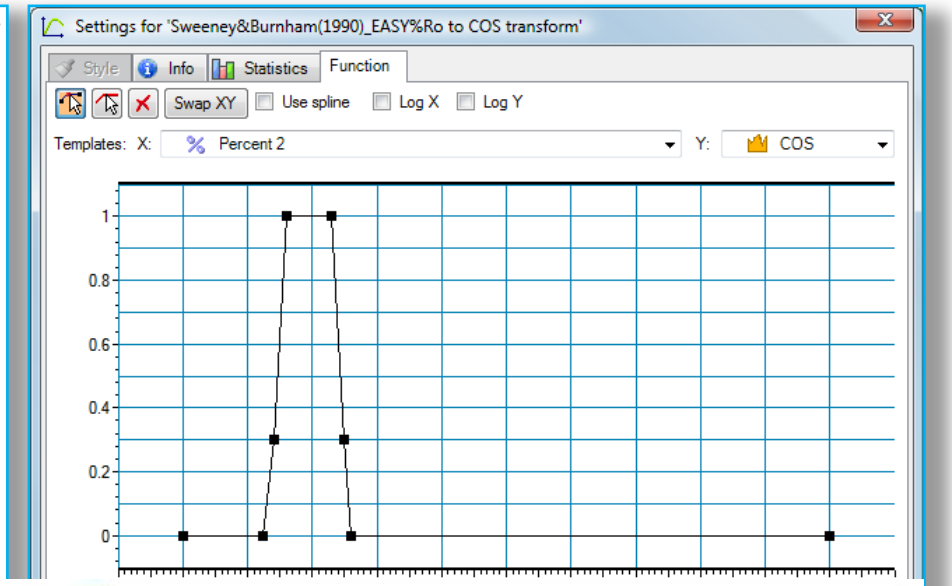


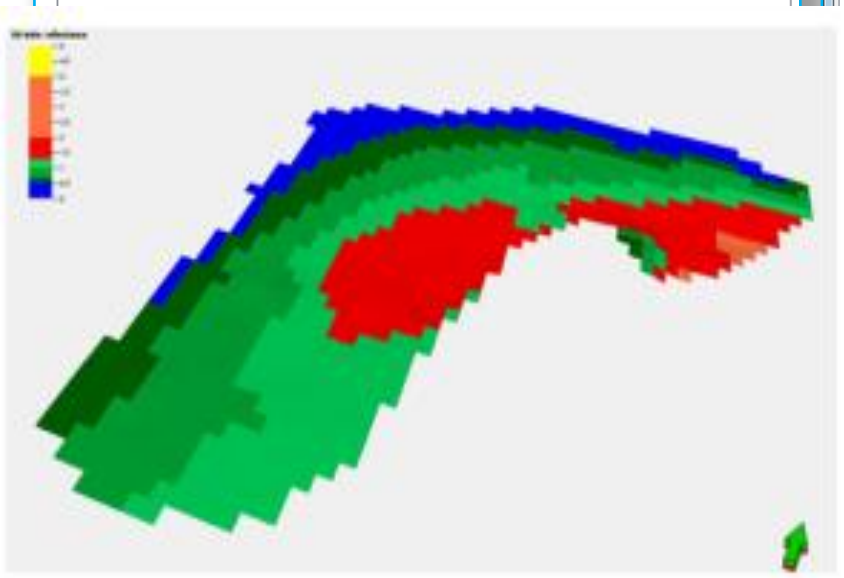
Gas in Place
0 - 1

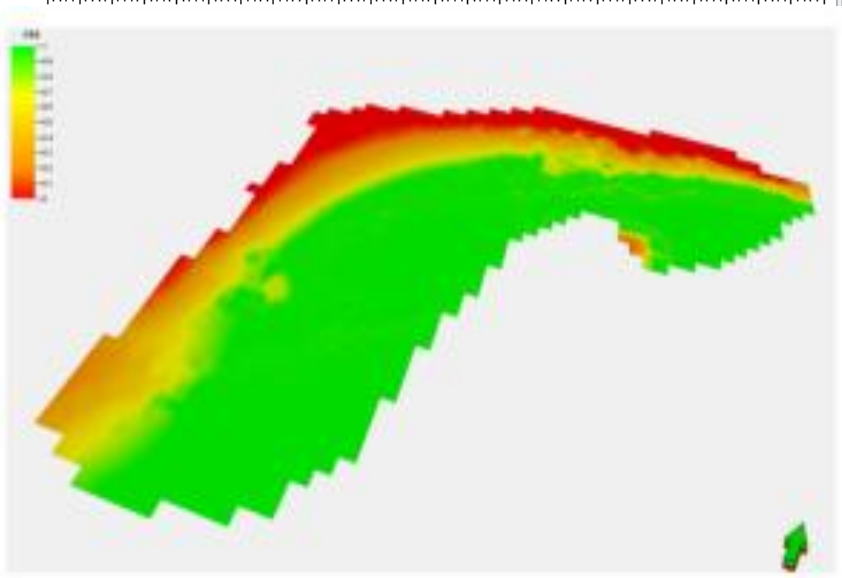
From Neber *et al*., 2012. SPE 158571

Play Chance Mapping



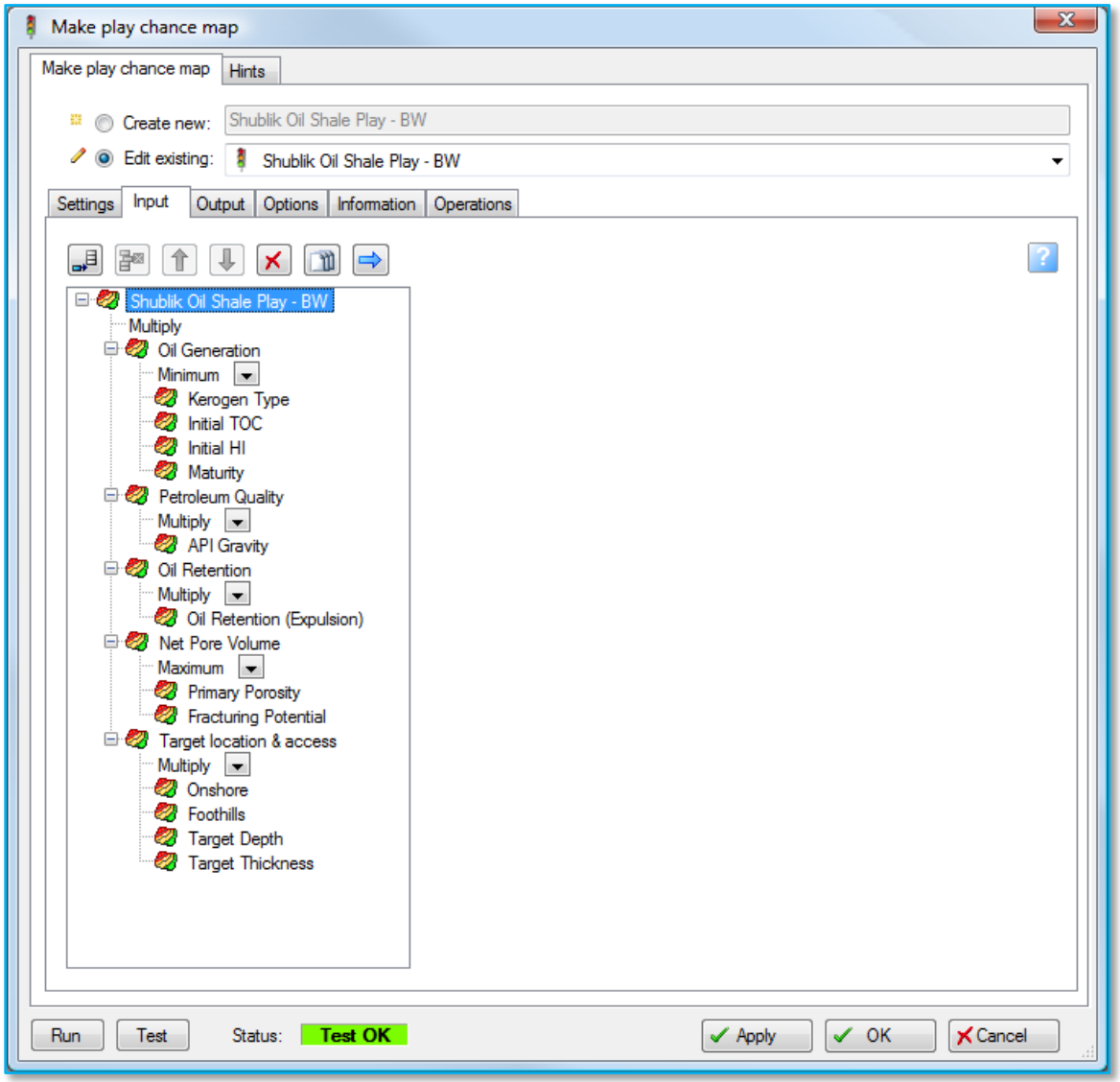






From Neber *et al.*, 2012. SPE 158571

Calculation of Total Play Risk



From Neber *et al.*, 2012. SPE 158571

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Data-poor Environment – Proof of Concept

Exploration in new shale gas plays offer E&P companies a first mover advantage, namely to acquire acreage in sweet spots before license costs escalate

How to find those sweet spots prior to extensive drilling in the play?

- Leverage data from exploration for conventional targets
- Build integrated petroleum systems models to predict resource richness and guide exploration drilling

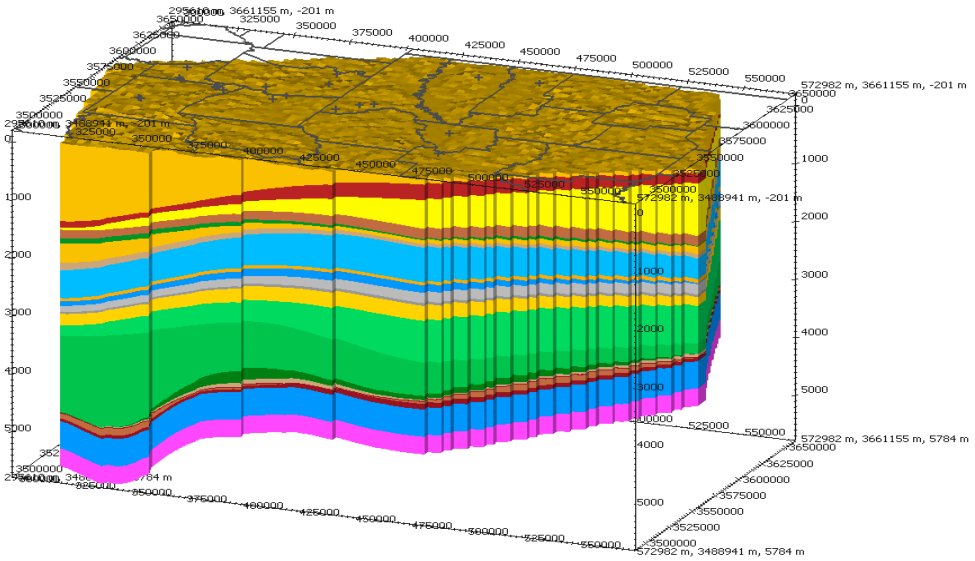
We simulated a data-poor environment by modeling the Haynesville shale gas play calibrated by only one well

The Haynesville Shale Gas Play

PetroMod Modeling

- Multi-component Generation
- Secondary Cracking
- Langmuir Adsorption
- Gas Generation Pressure
- Secondary Porosity
- Seal Quality: Fracturing Model

Model has uniform layer properties and is calibrated with **one** well



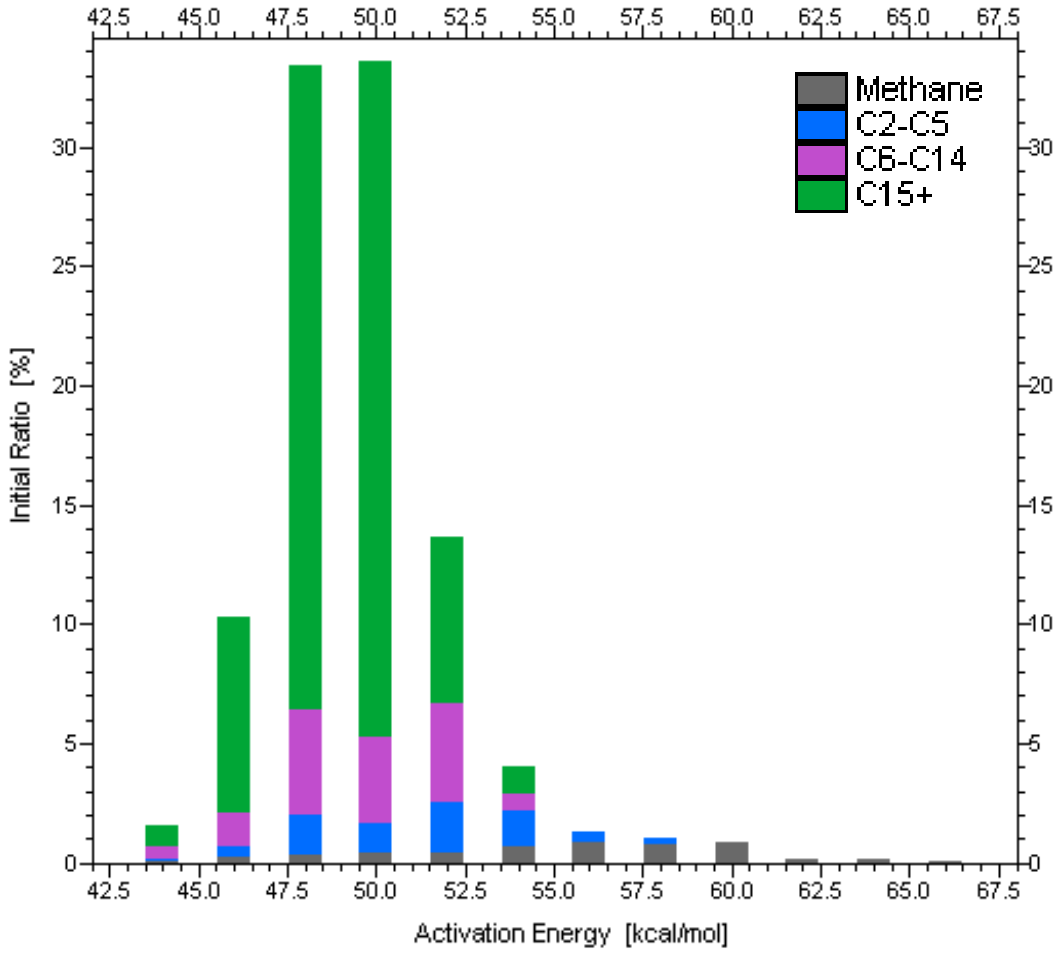
3D petroleum systems model: area ~ 270 x 180 km

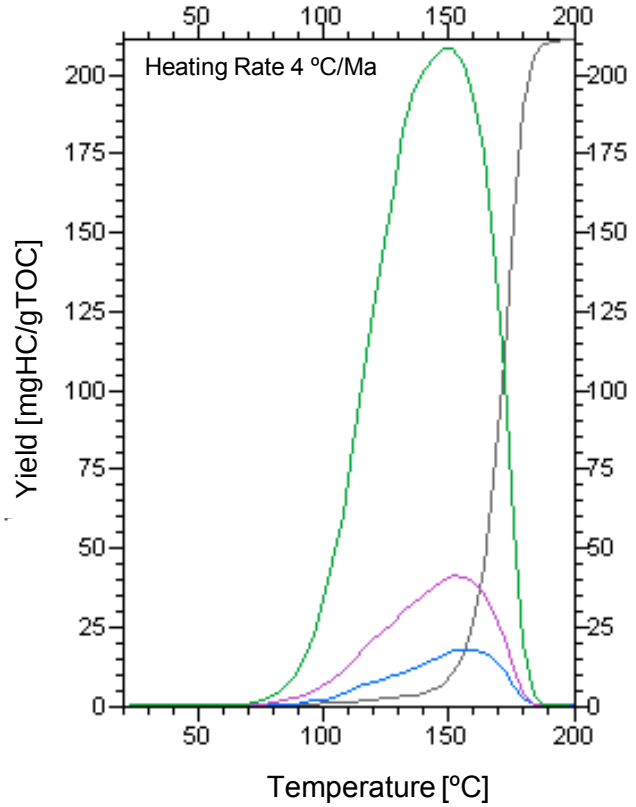
From Mavidou, 2010

Generation

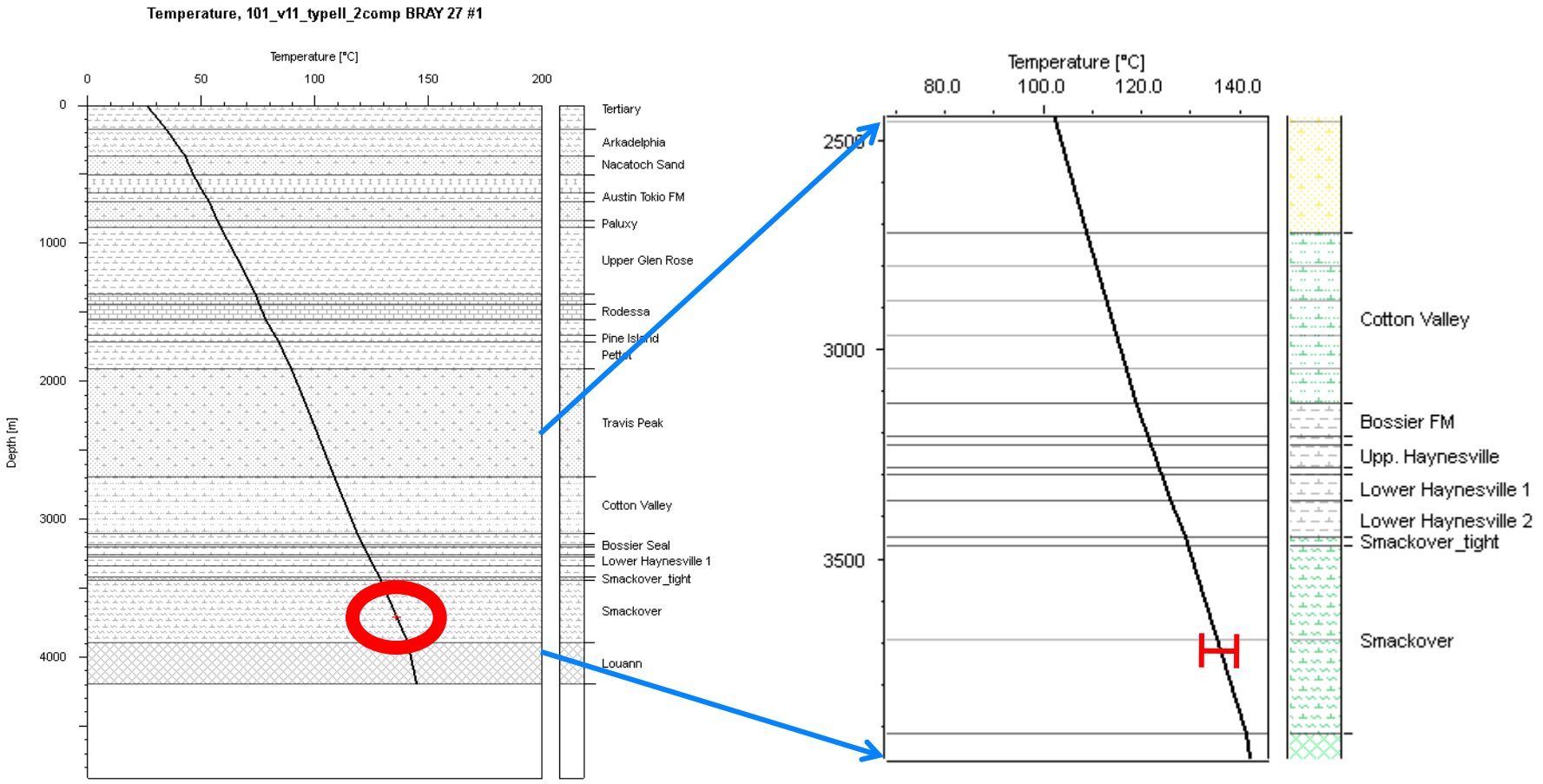
Here: modified 4 component Behar *et al.* (1997) TII kinetics:

- HI: 300 mgHC/gTOC: inert kerogen ~ 3.5 x generative kerogen
- Secondary cracking of all components to methane, E_a = 58 kcal/mol



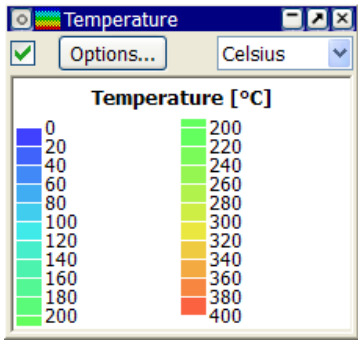


Calibration of Temperature

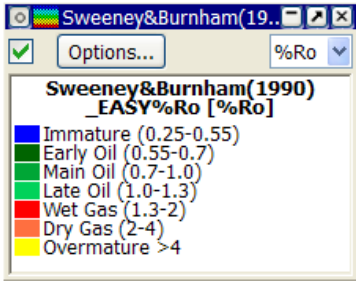


Temperature and Maturity

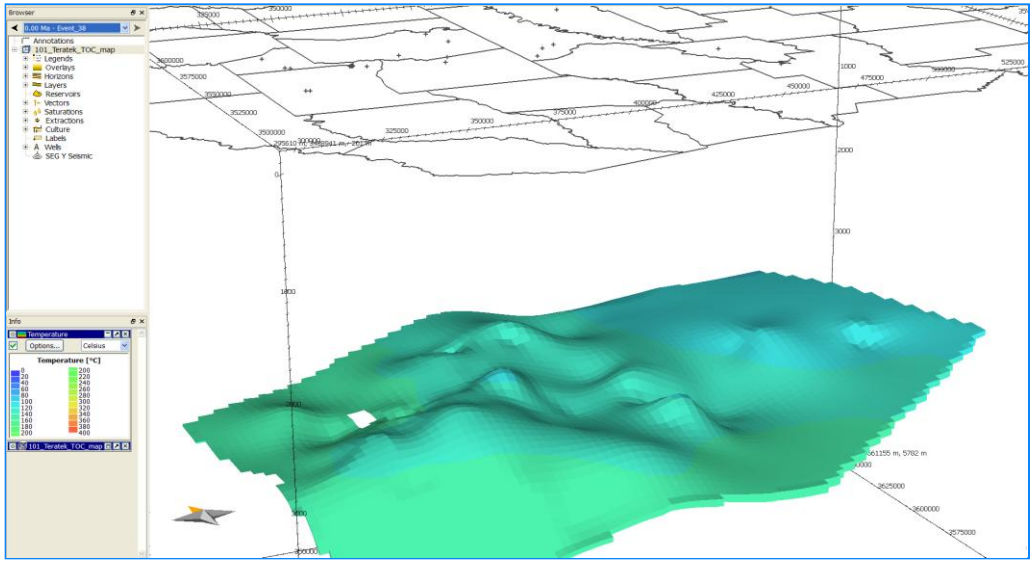
Temperature

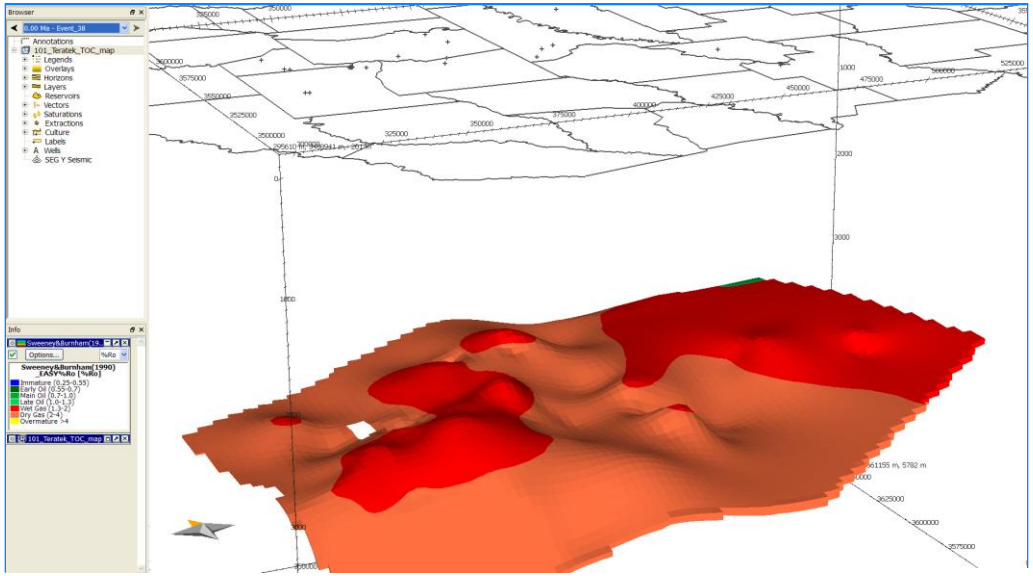


Vitrinite Reflection (Maturity)

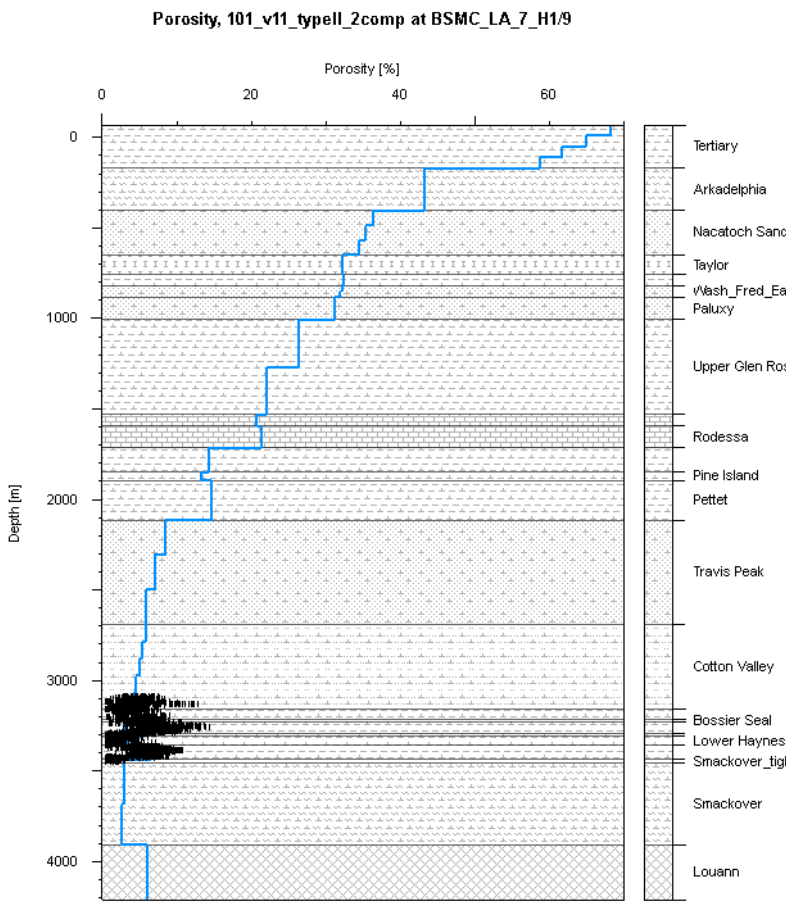


present

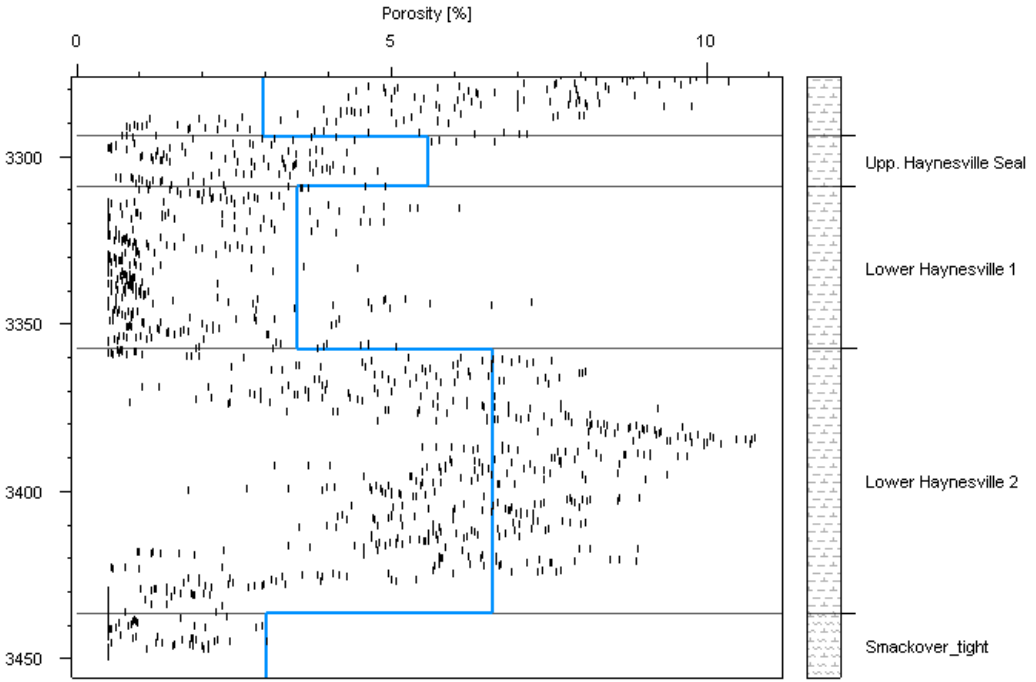




Calibration of Porosities



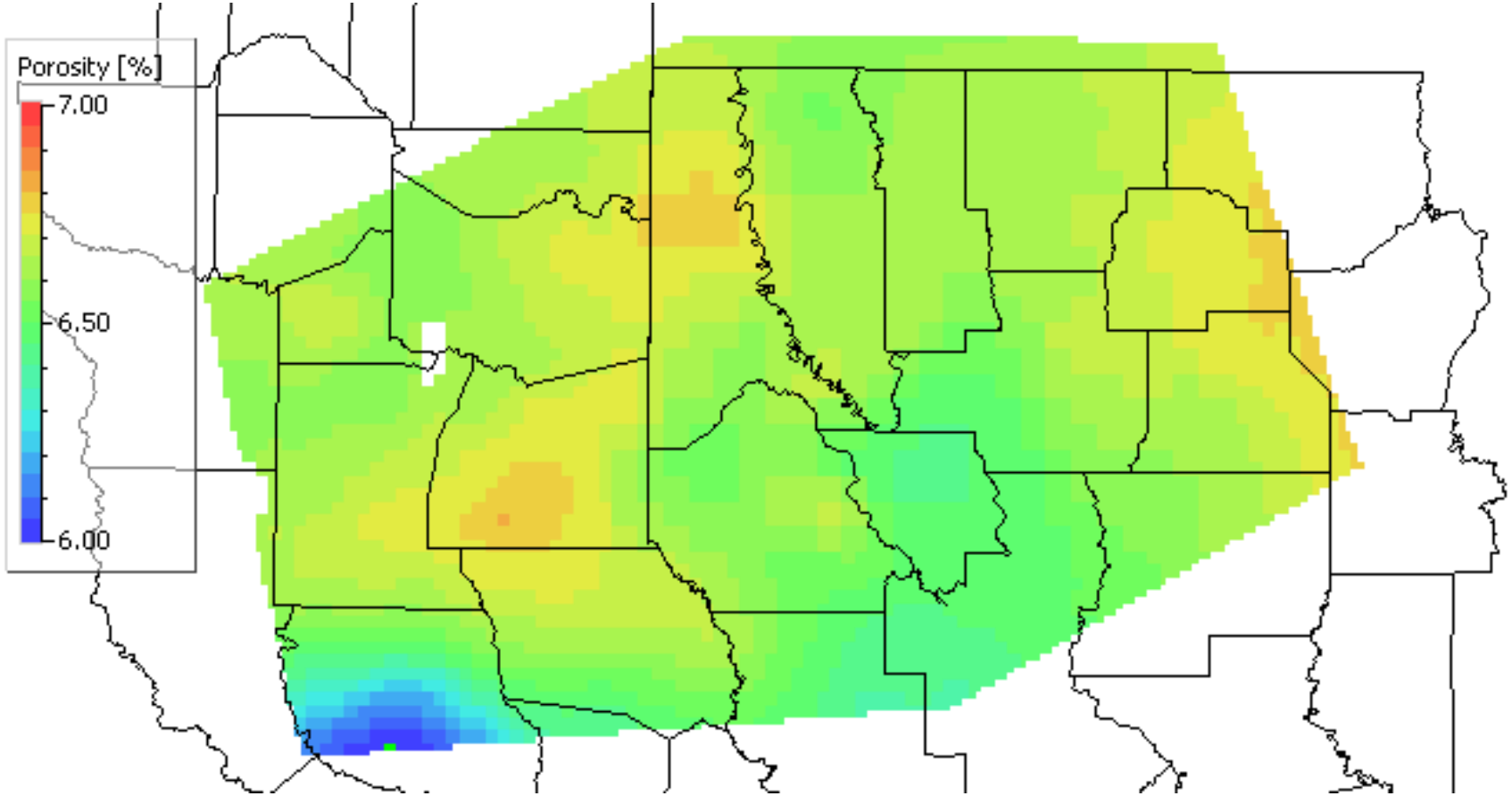
Data from Petrel Project



Modeling of Porosity

Average: ~ 6.5%

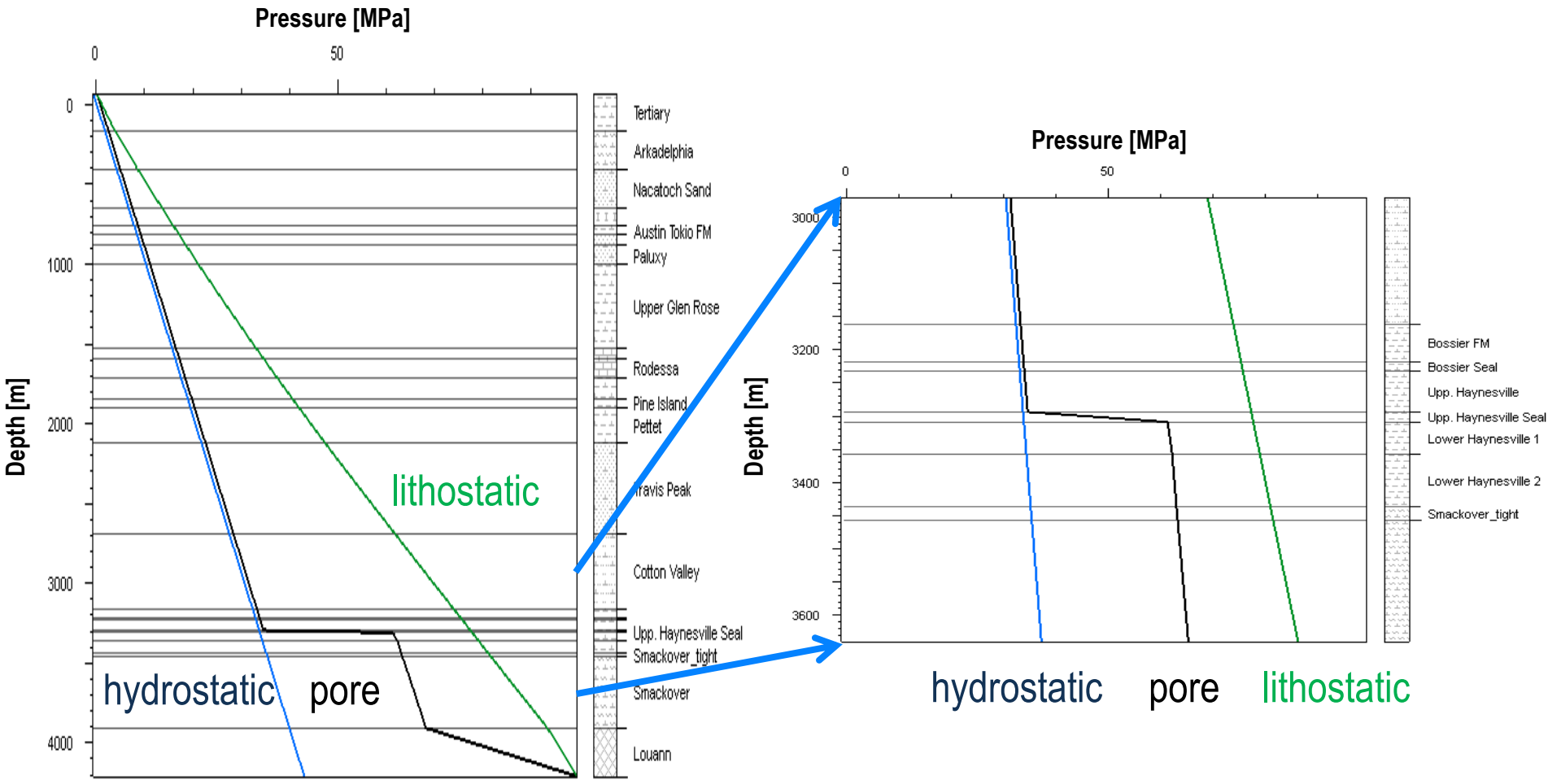
Published[1]: 6 - 10%



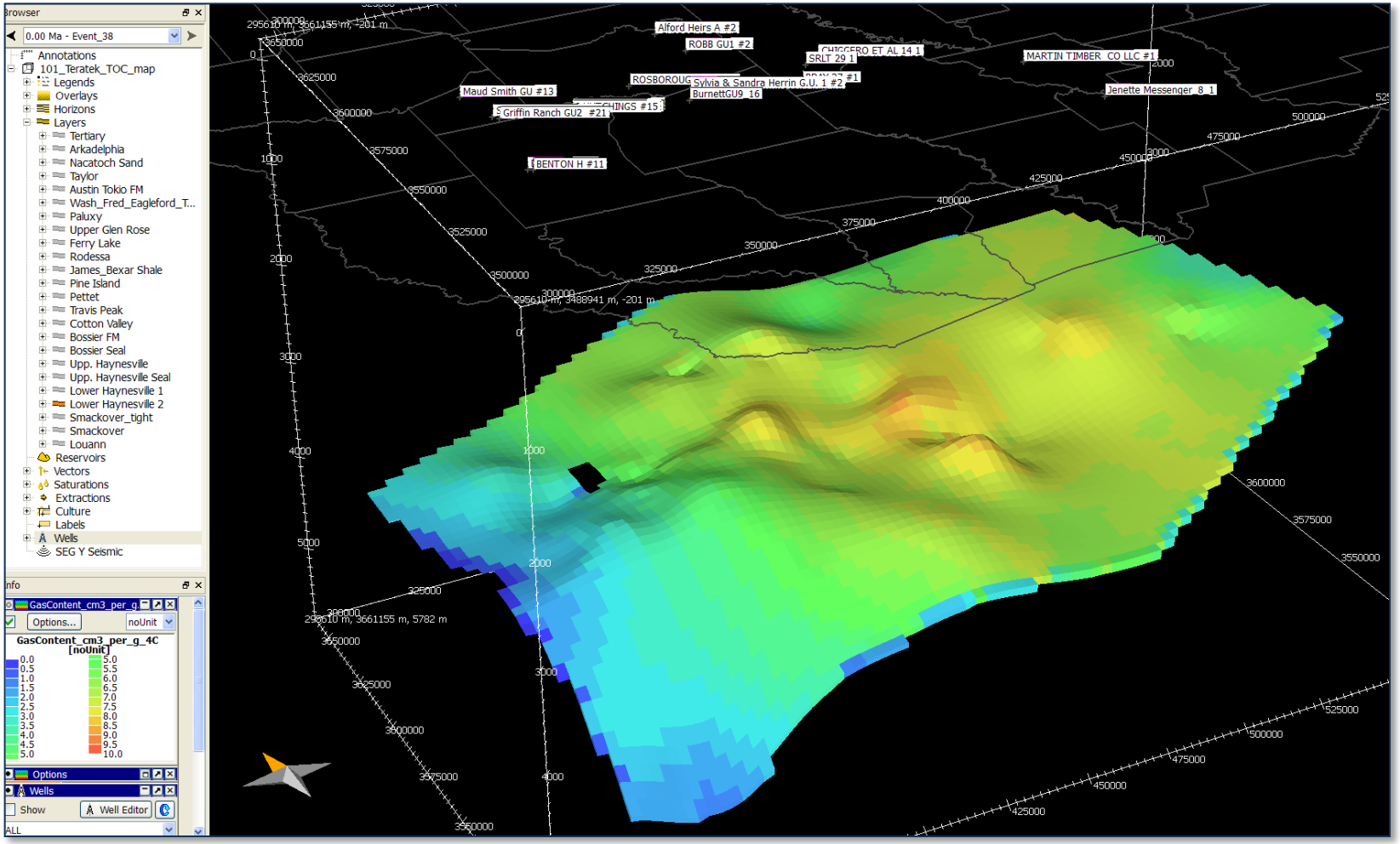
[1] *Bresch and Carpenter (2009), U.S. Department of Energy (2009)*

Secondary porosity due to conversion of kerogen to hydrocarbons and pressure build-up due to corresponding volume expansion is incorporated

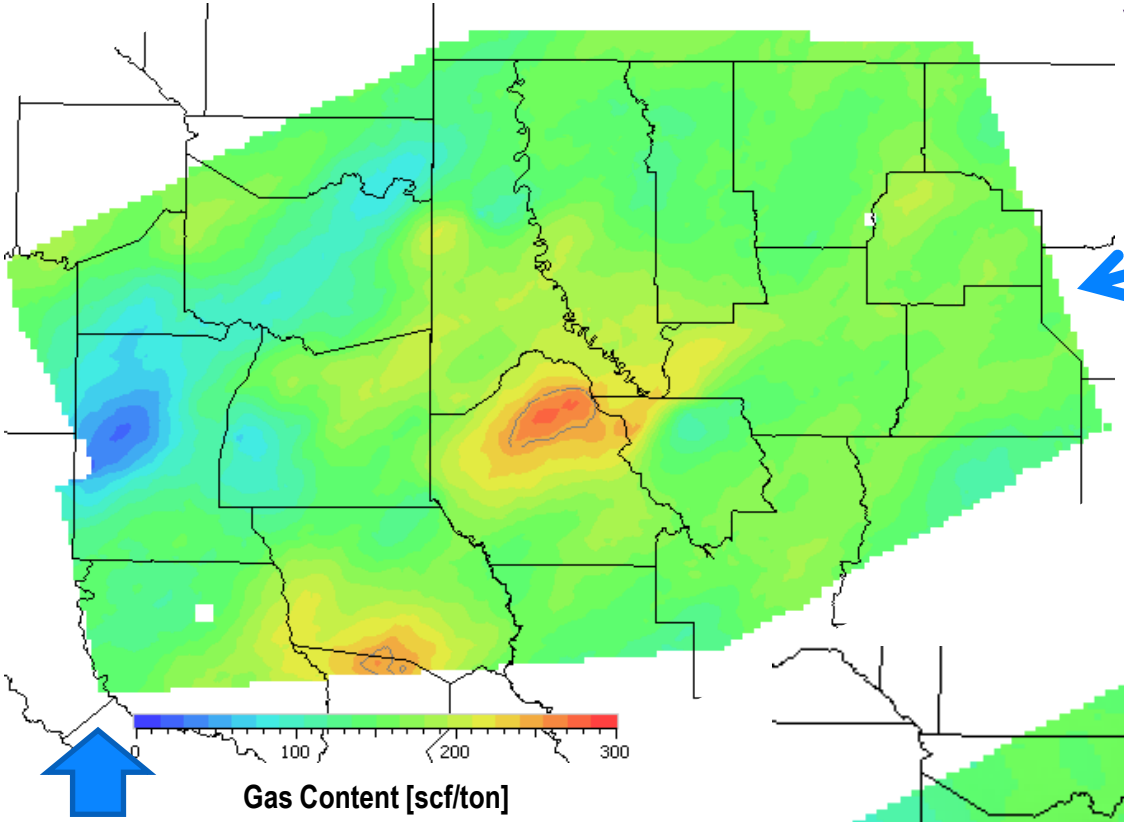
Calibration of Pressures



Gas Resource in Place



Validation

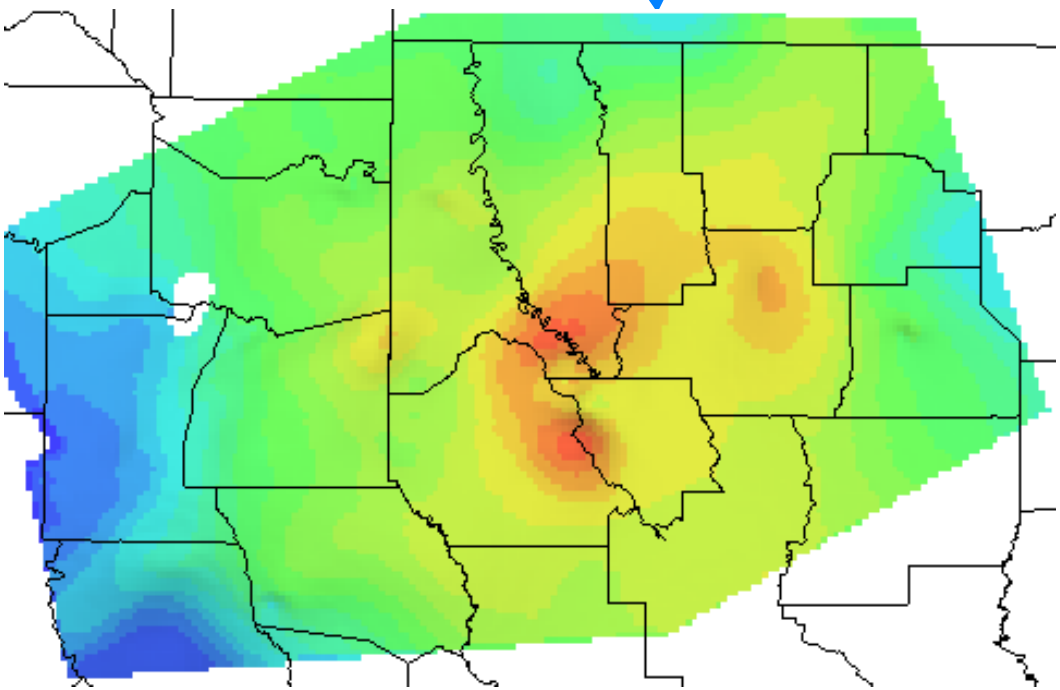


U.S. DoE

Measured gas content
Average 200 scf/ton
Maximum 275 scf/ton

Modeling

Modeled gas content
Average 220 scf/ton
Maximum 280 scf/ton



Summary – Haynesville Shale Play

- In-place resource estimates are similar to those established after extensive drilling in the Haynesville shale play
- Valid approach for exploration early in the life of unconventional resource plays

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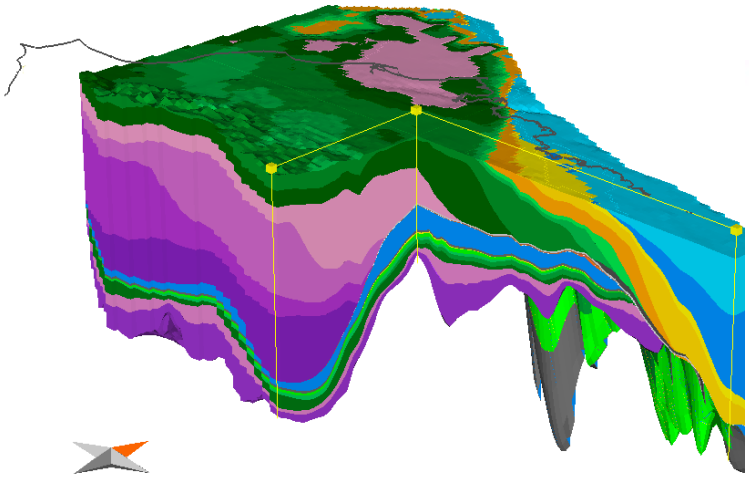
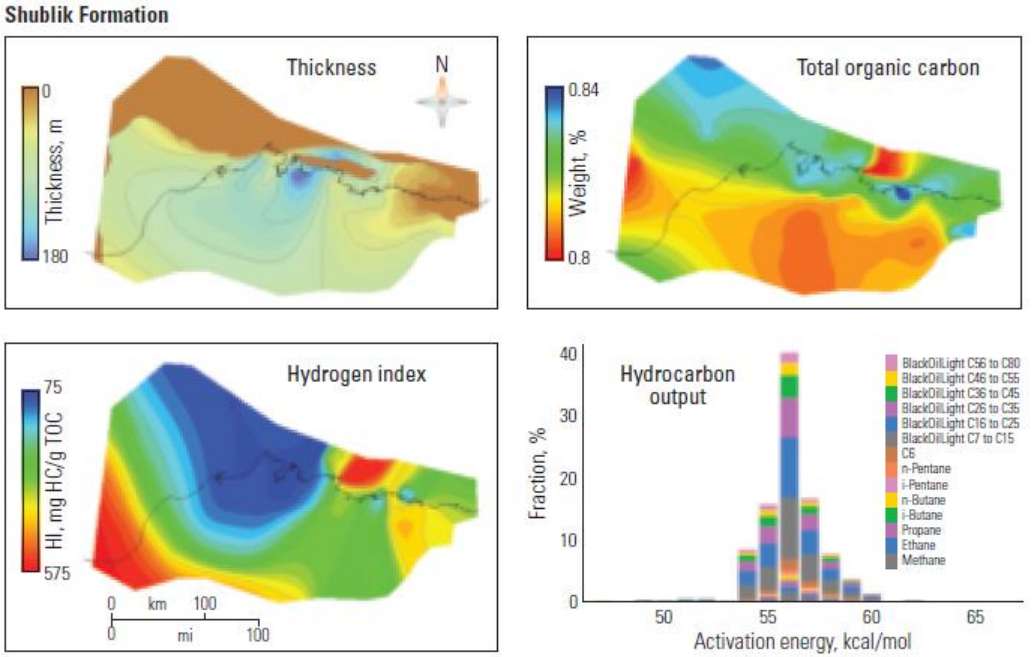
Alaska North Slope Model



USGS
science for a changing world



Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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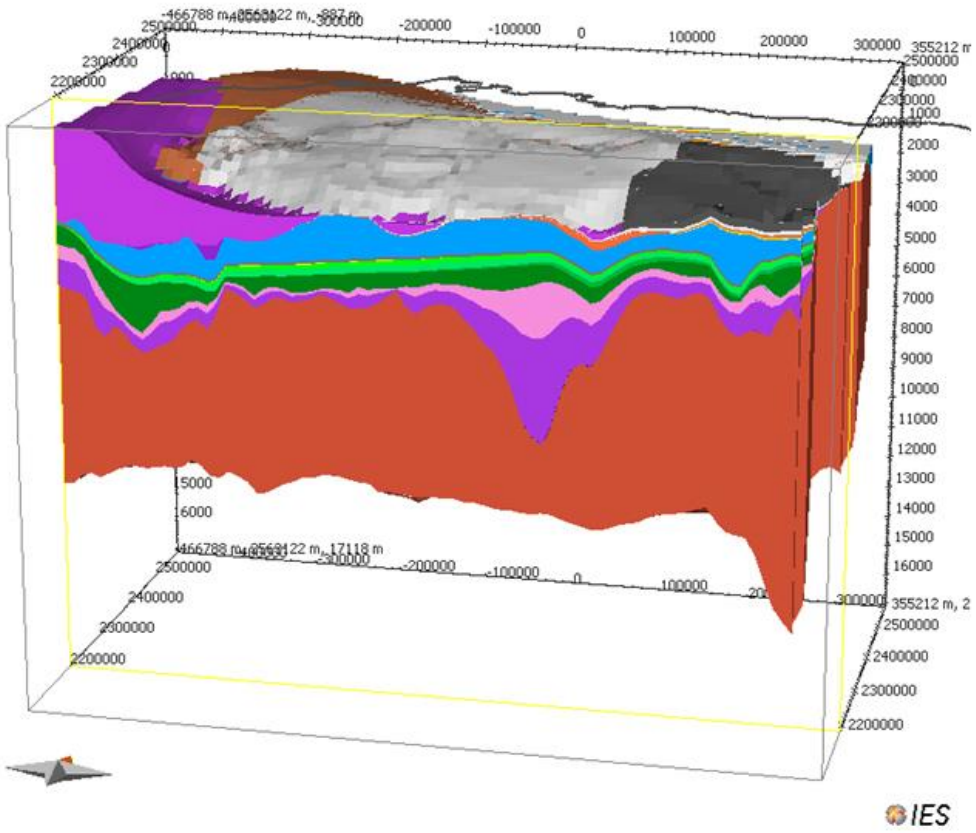

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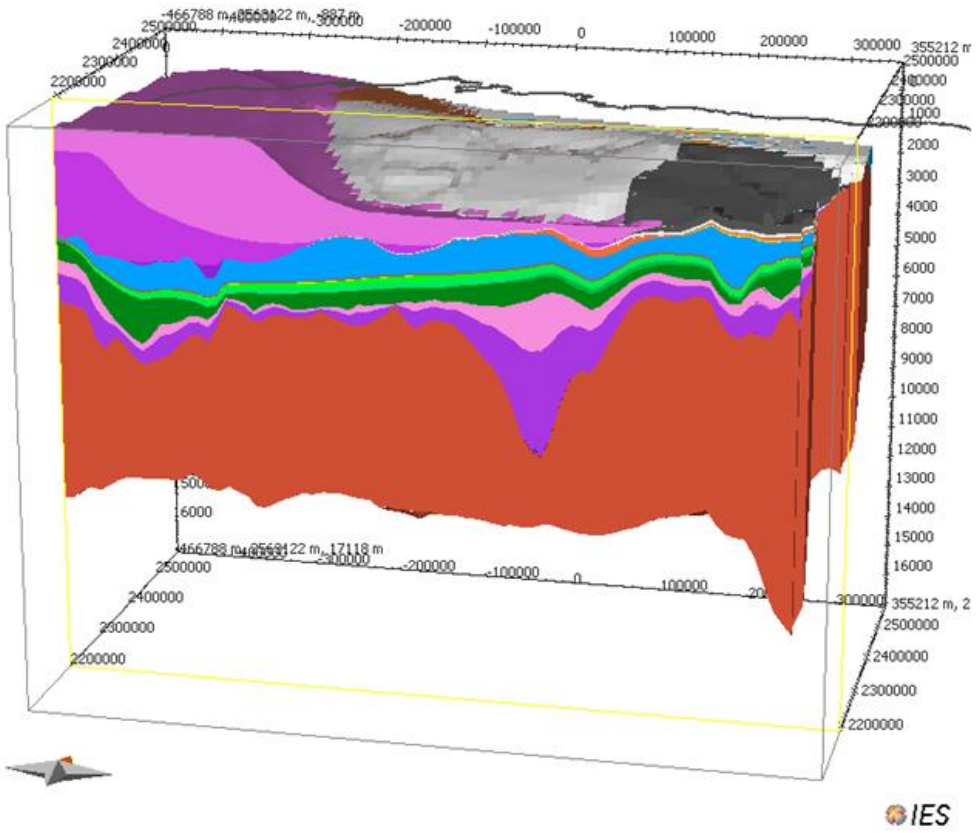

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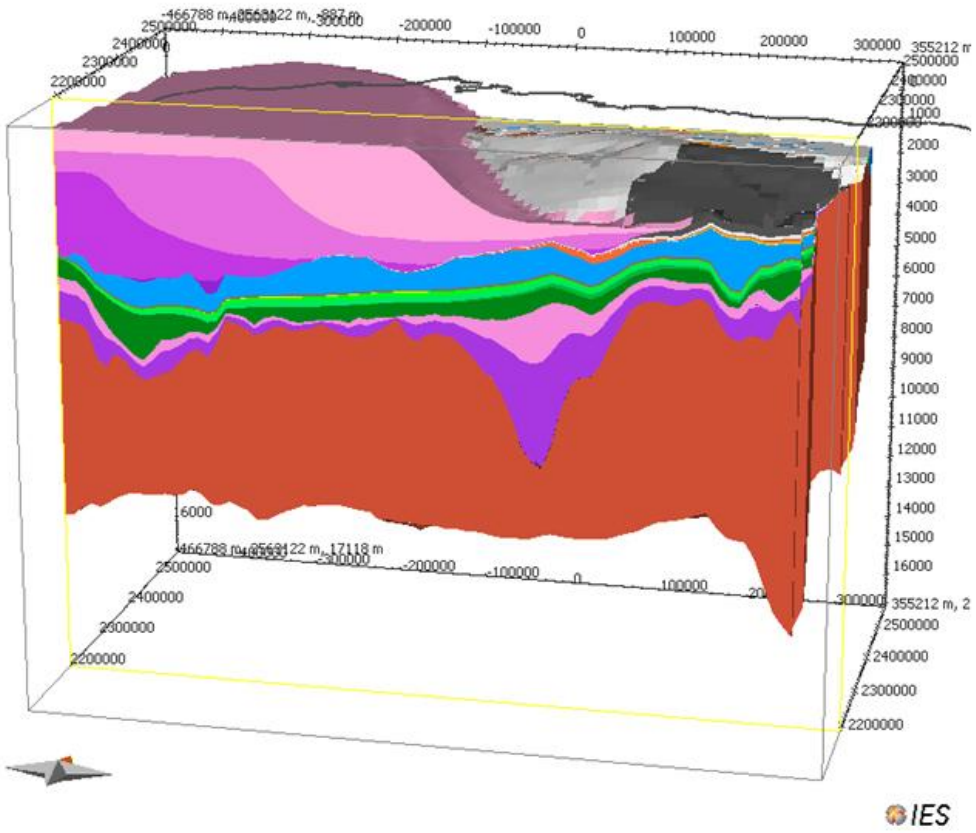

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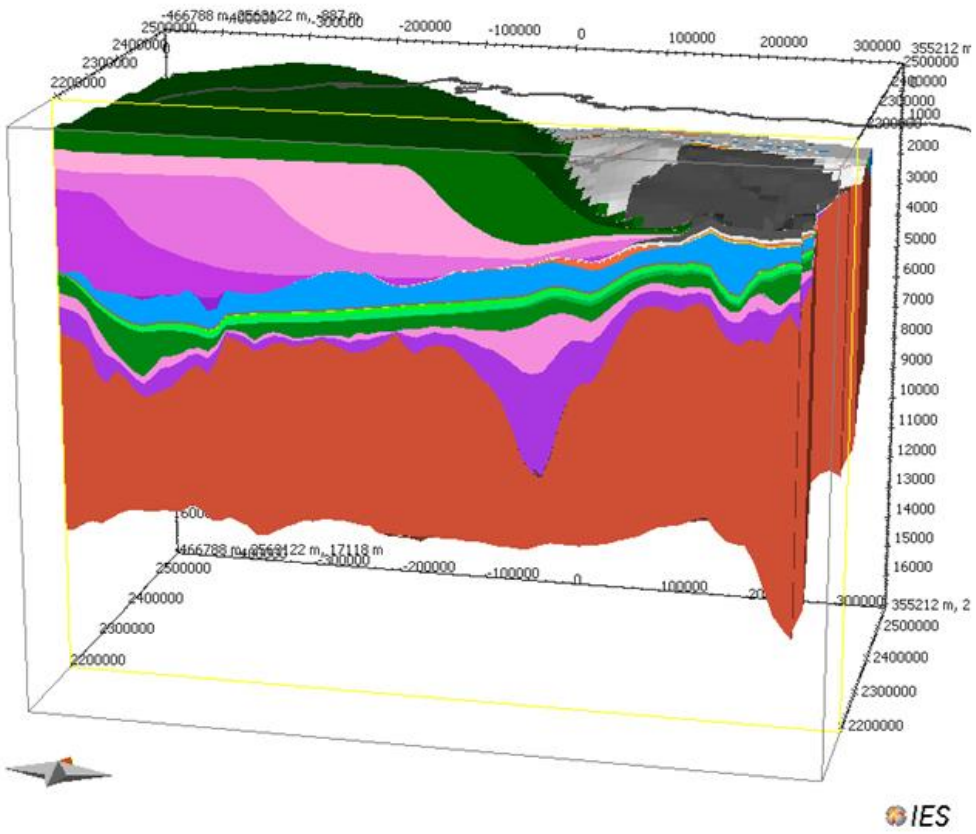

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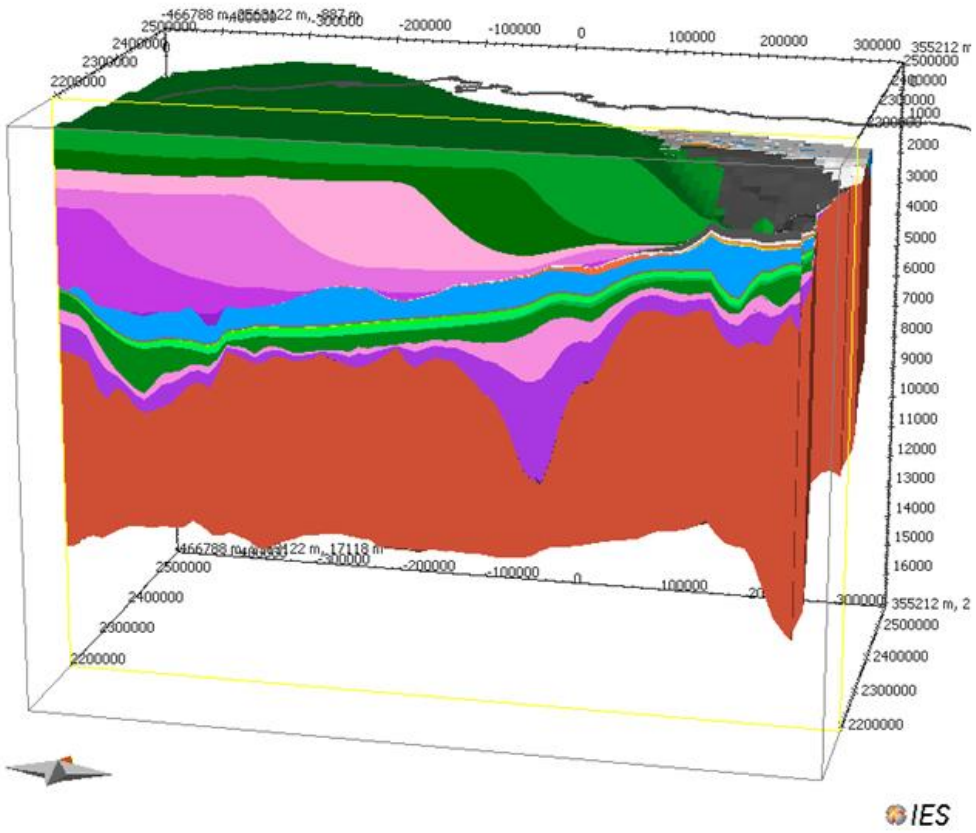

USGS science for a changing world

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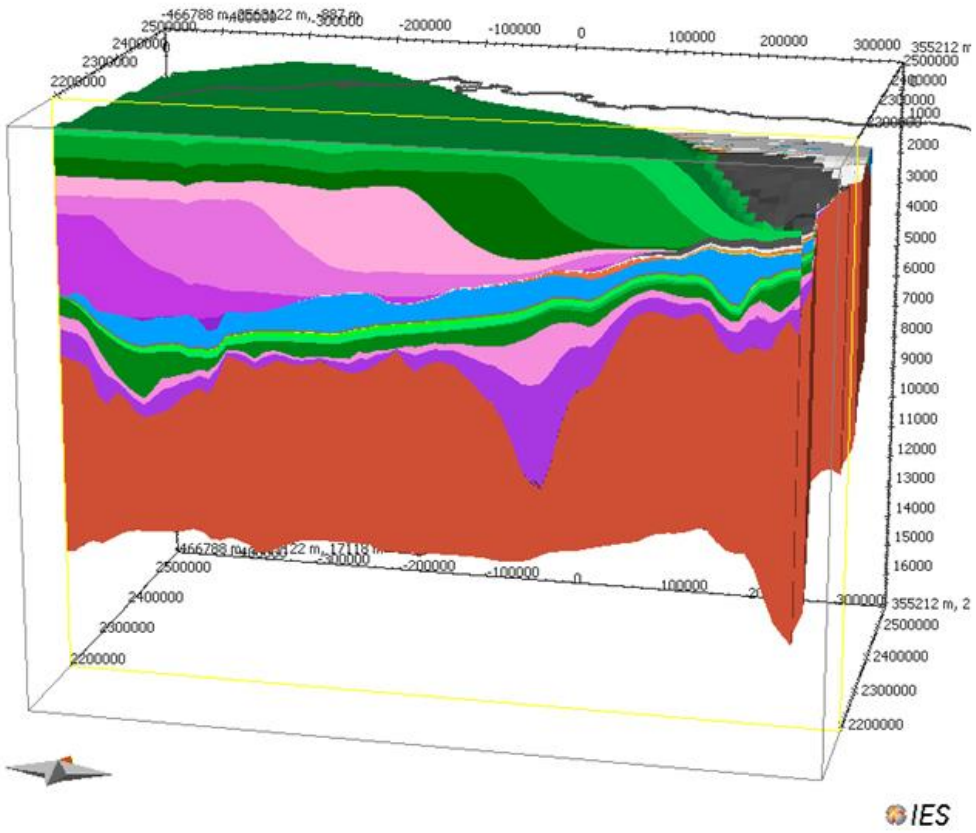

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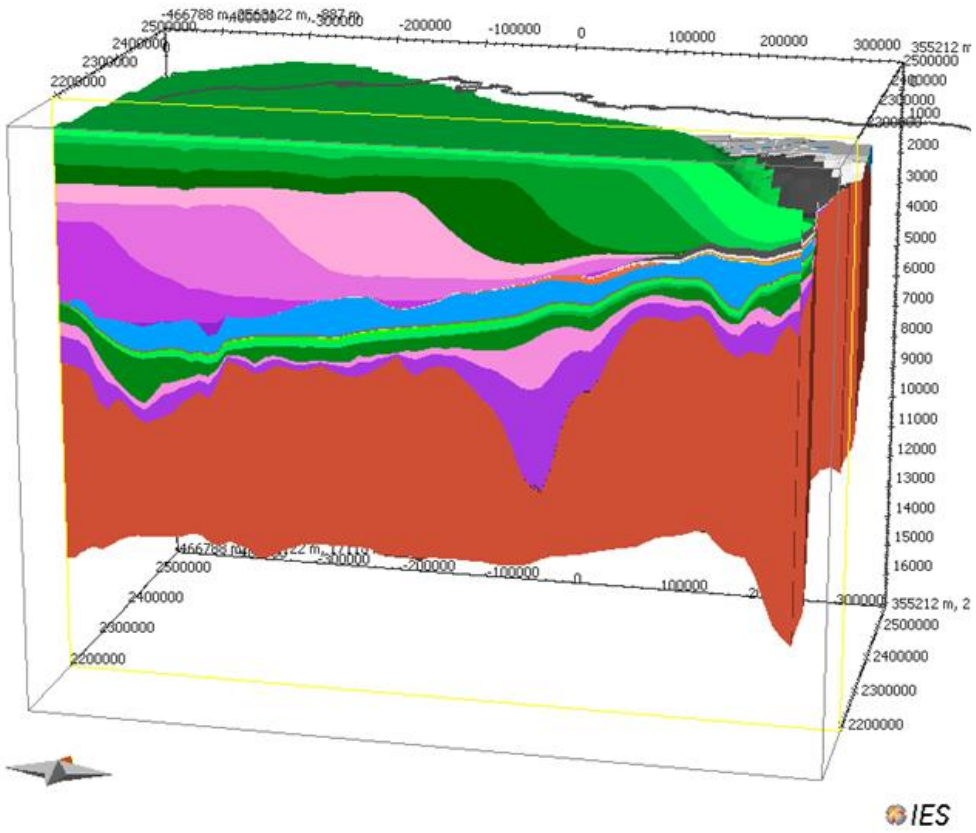

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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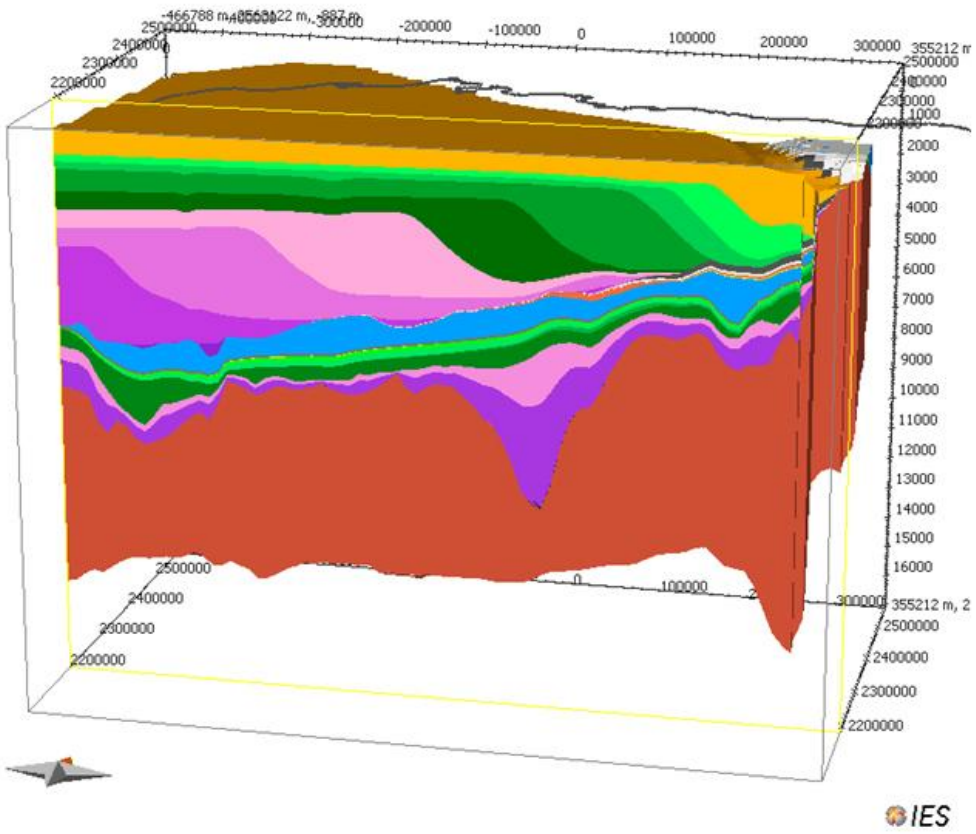

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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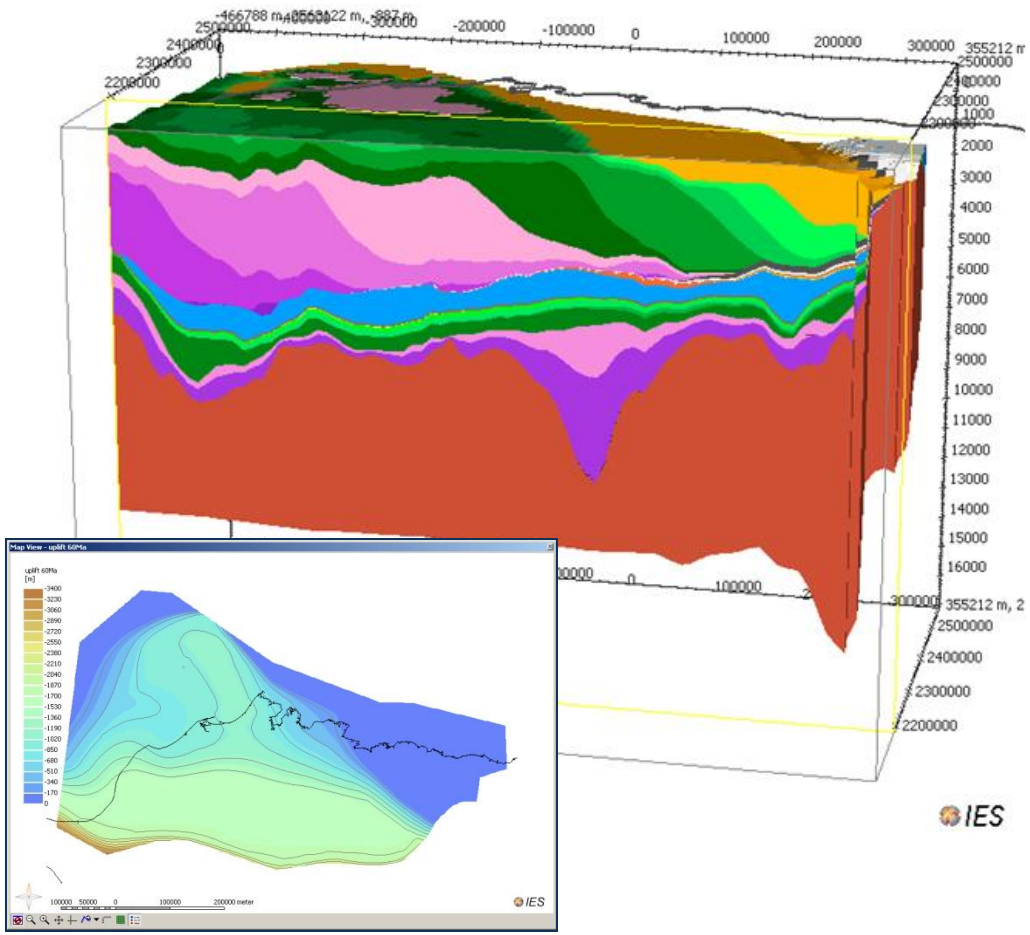

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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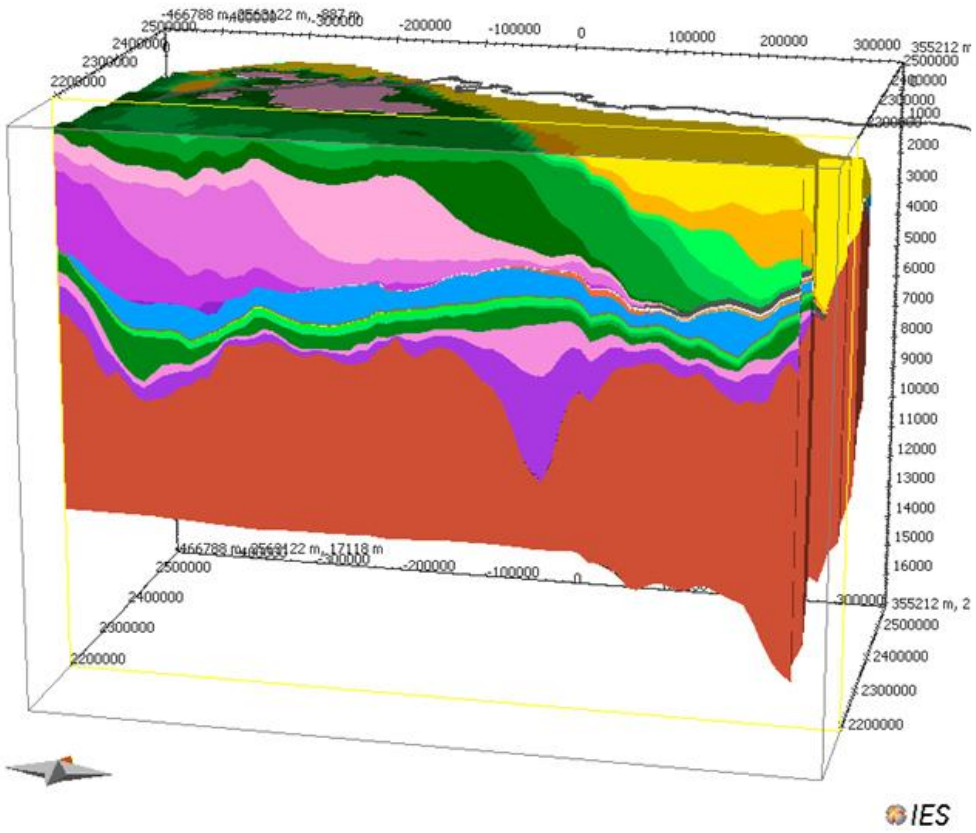

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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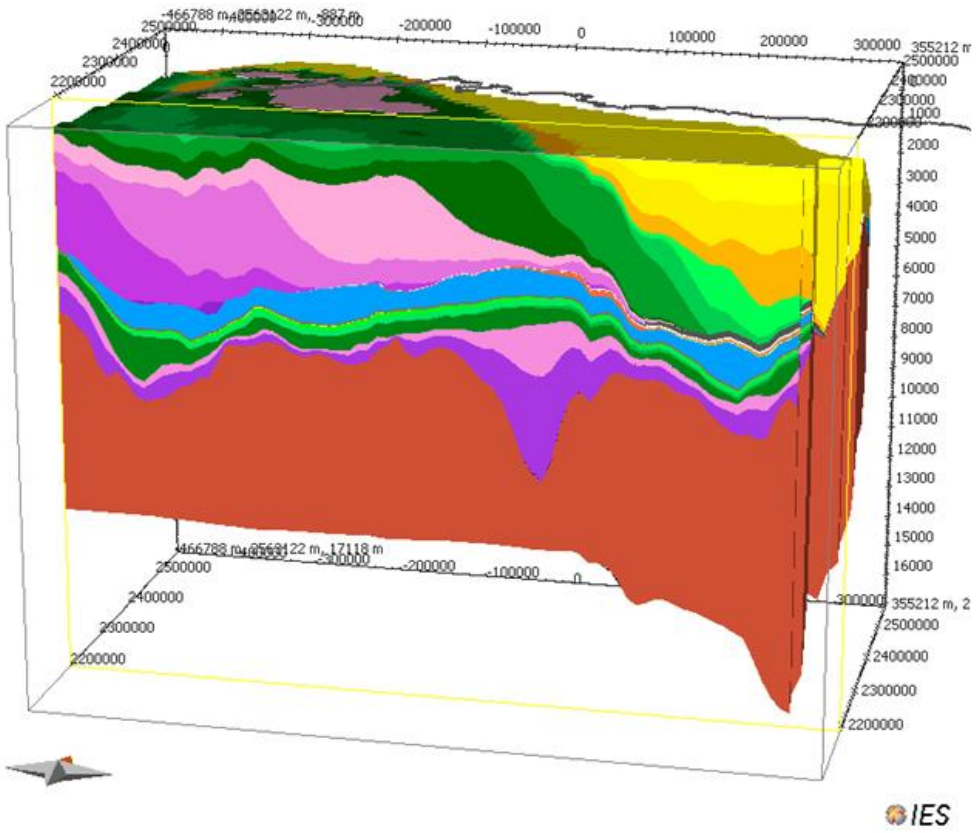

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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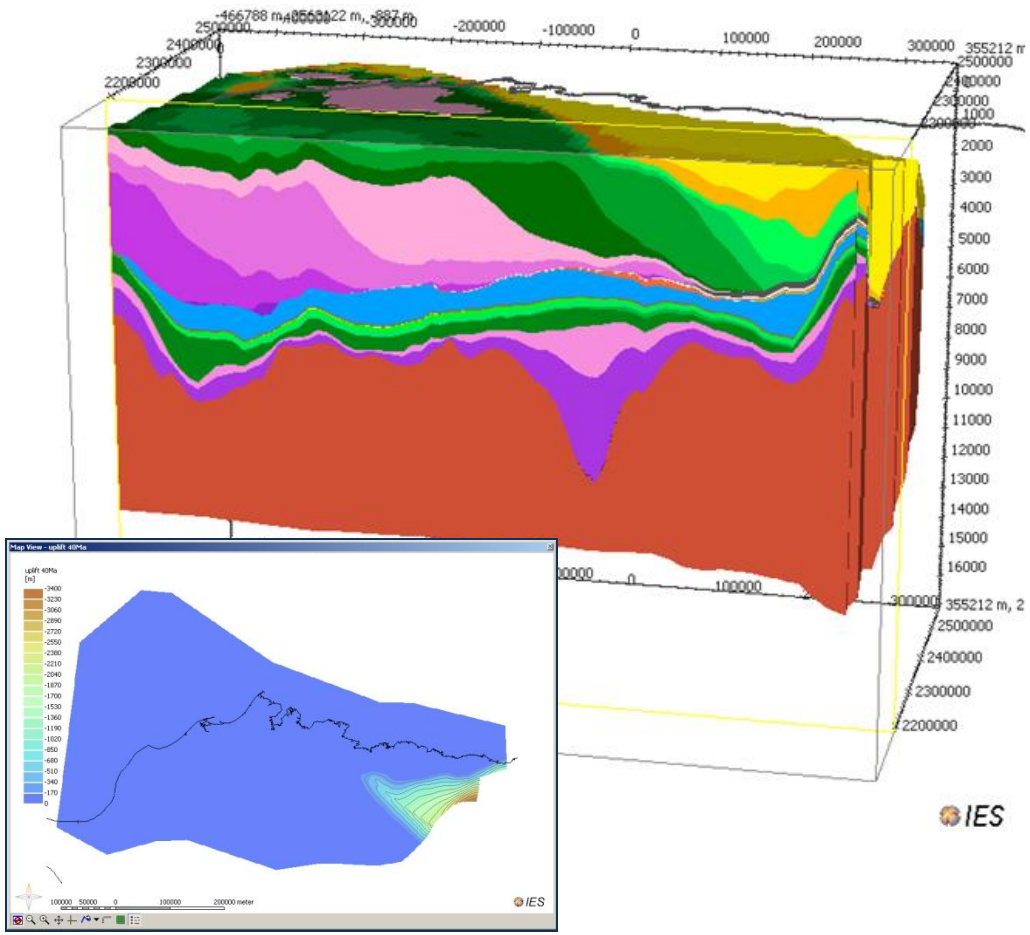

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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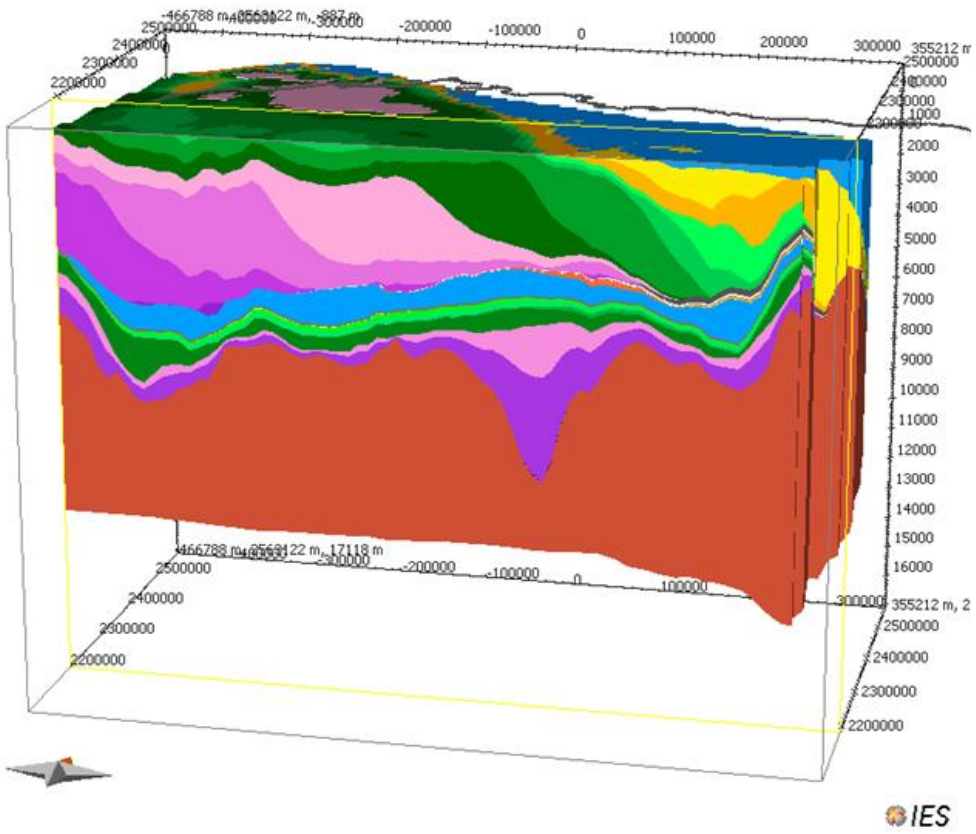

Alaska North Slope - 3D Petroleum Systems Model

Geological History: *Reconstructed Brookian sequence*

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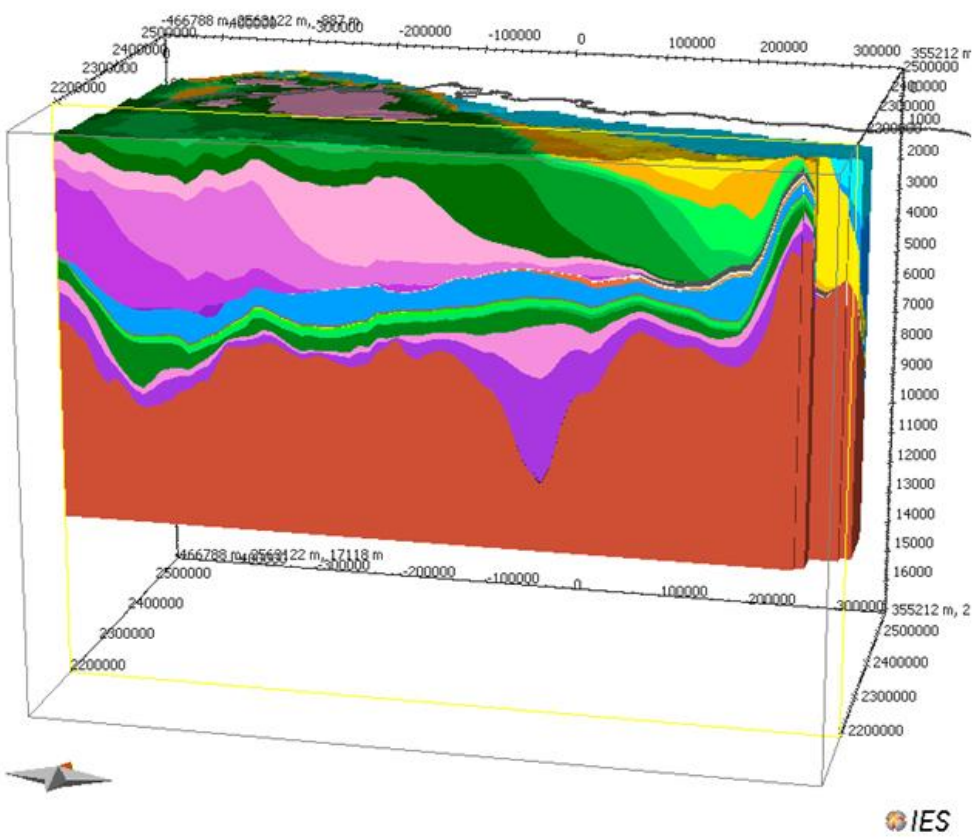

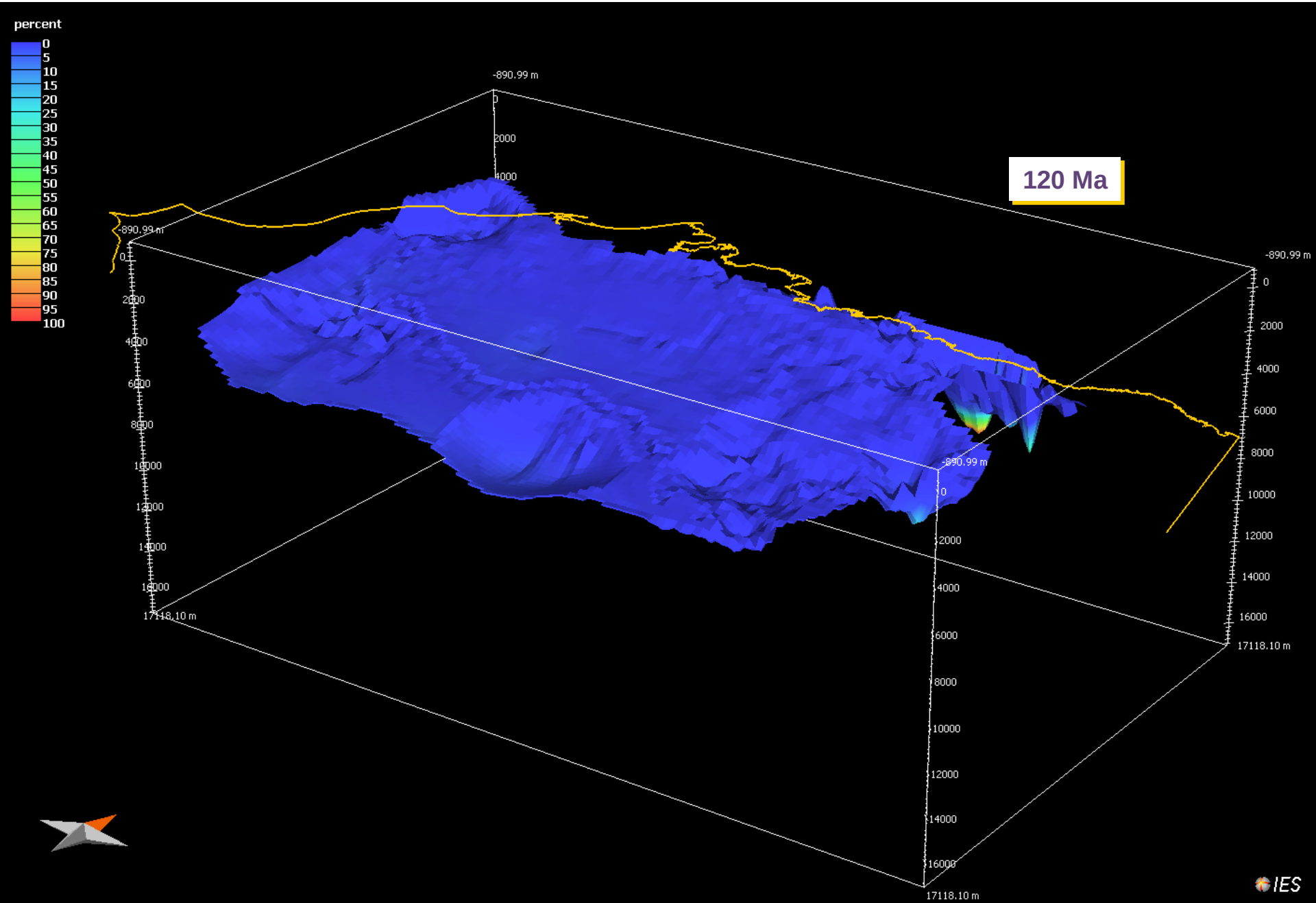
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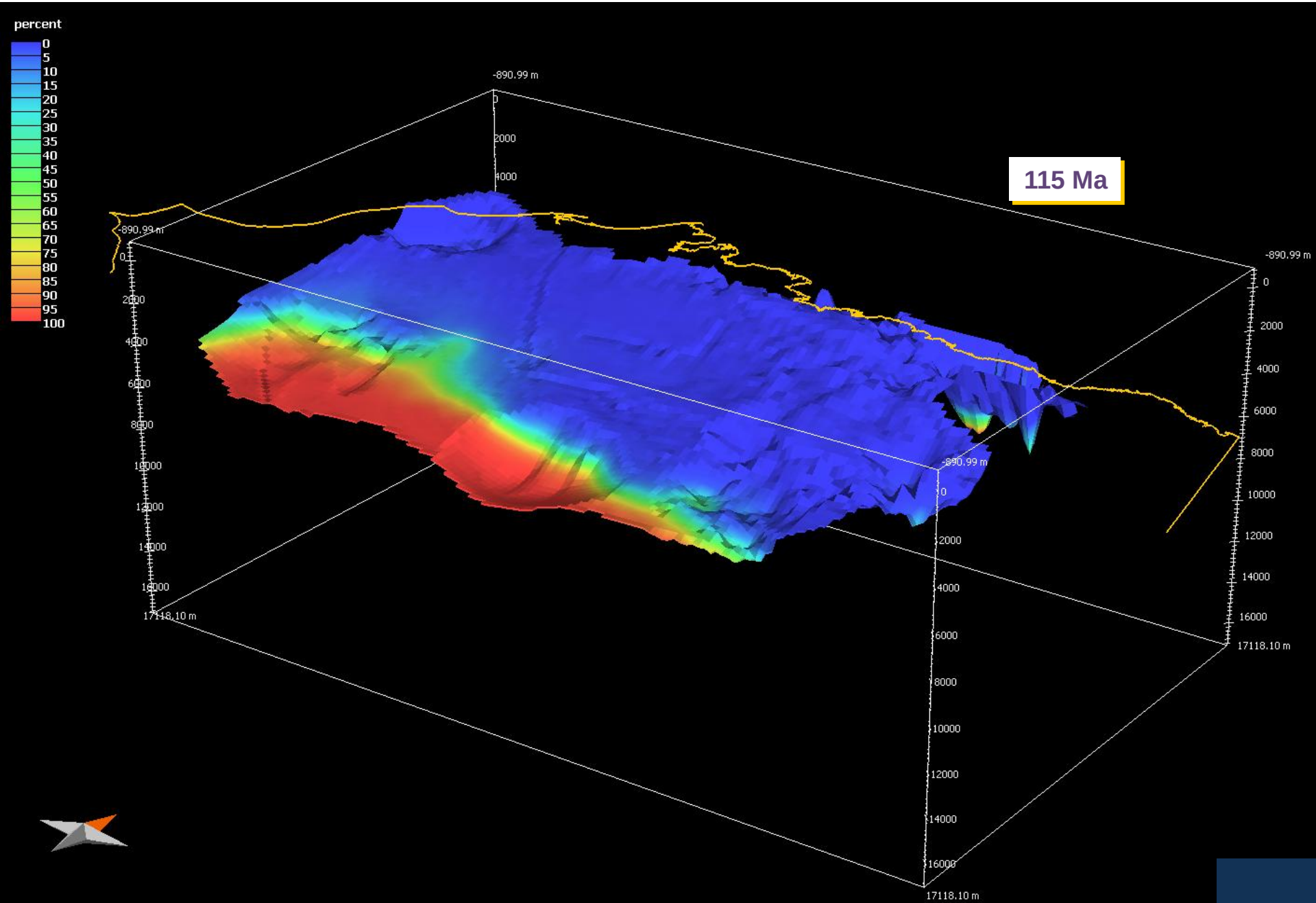
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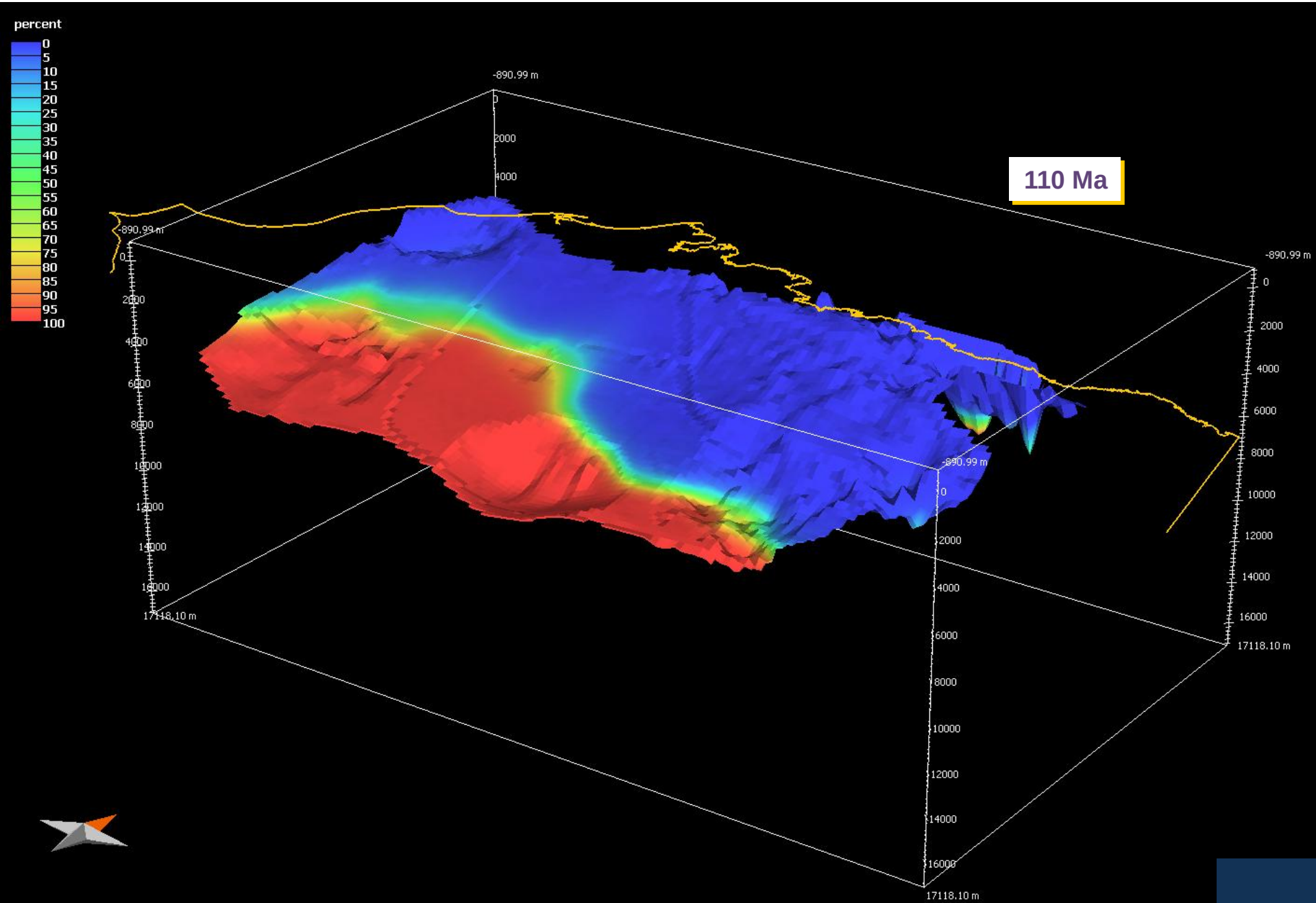
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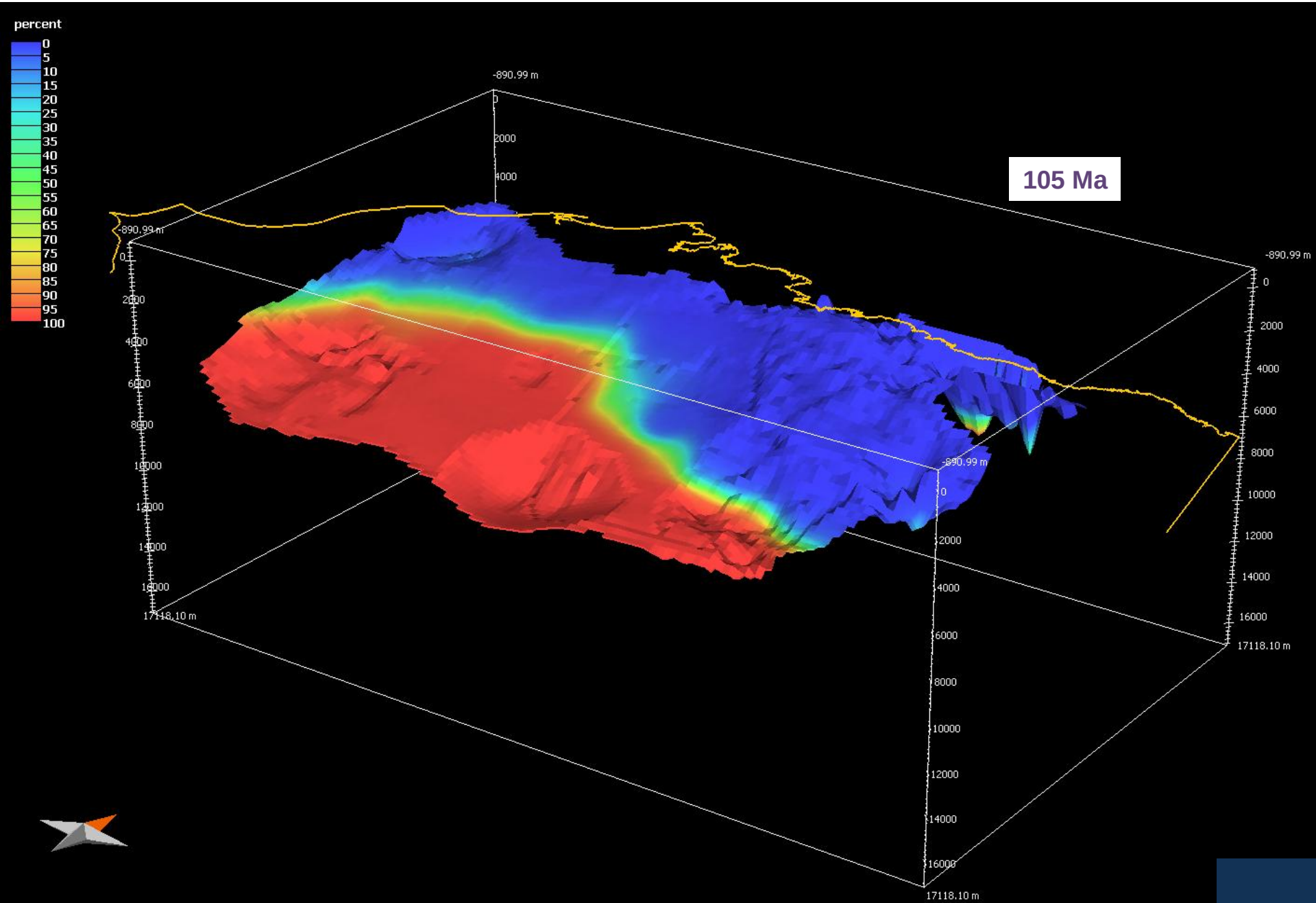
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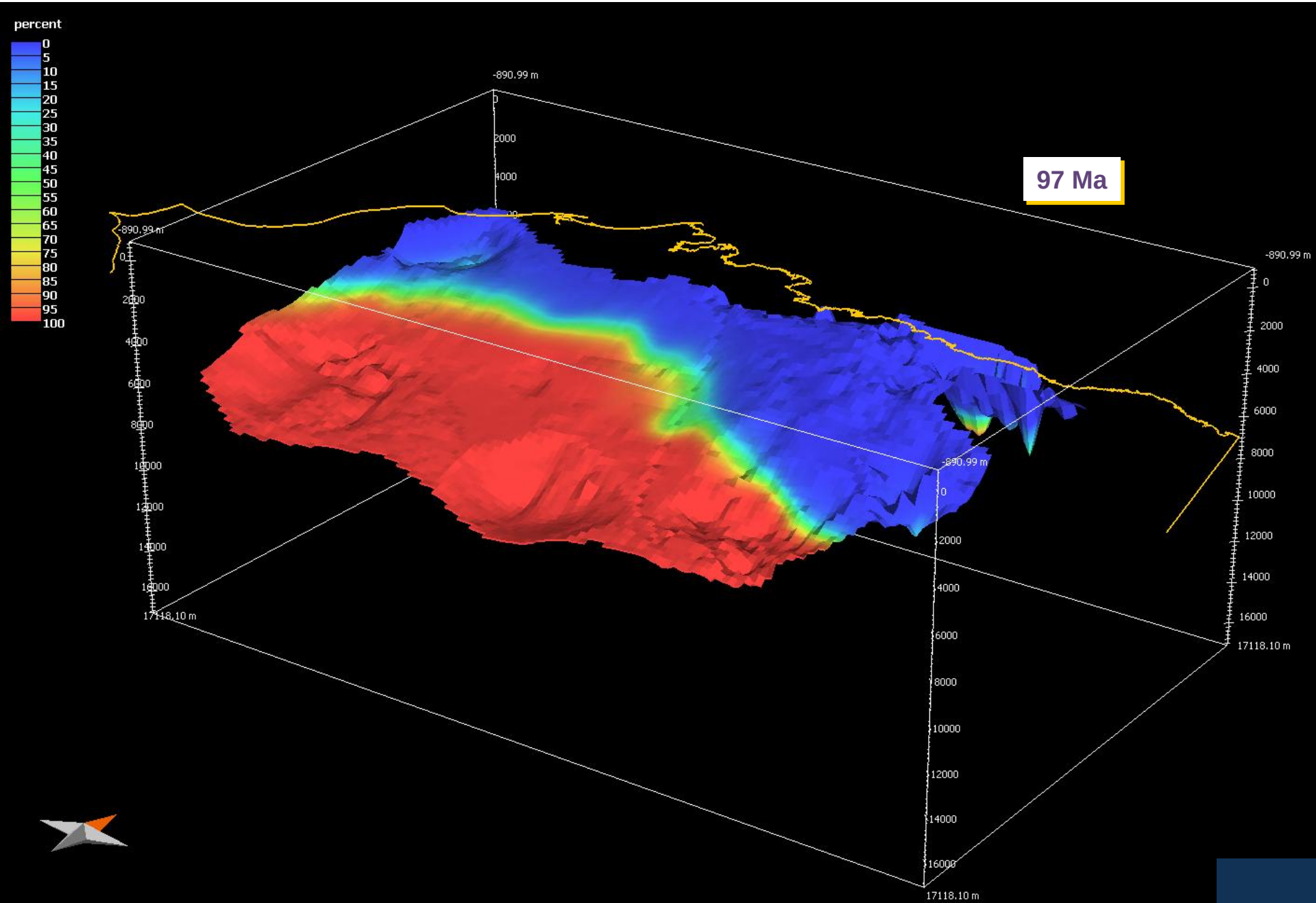
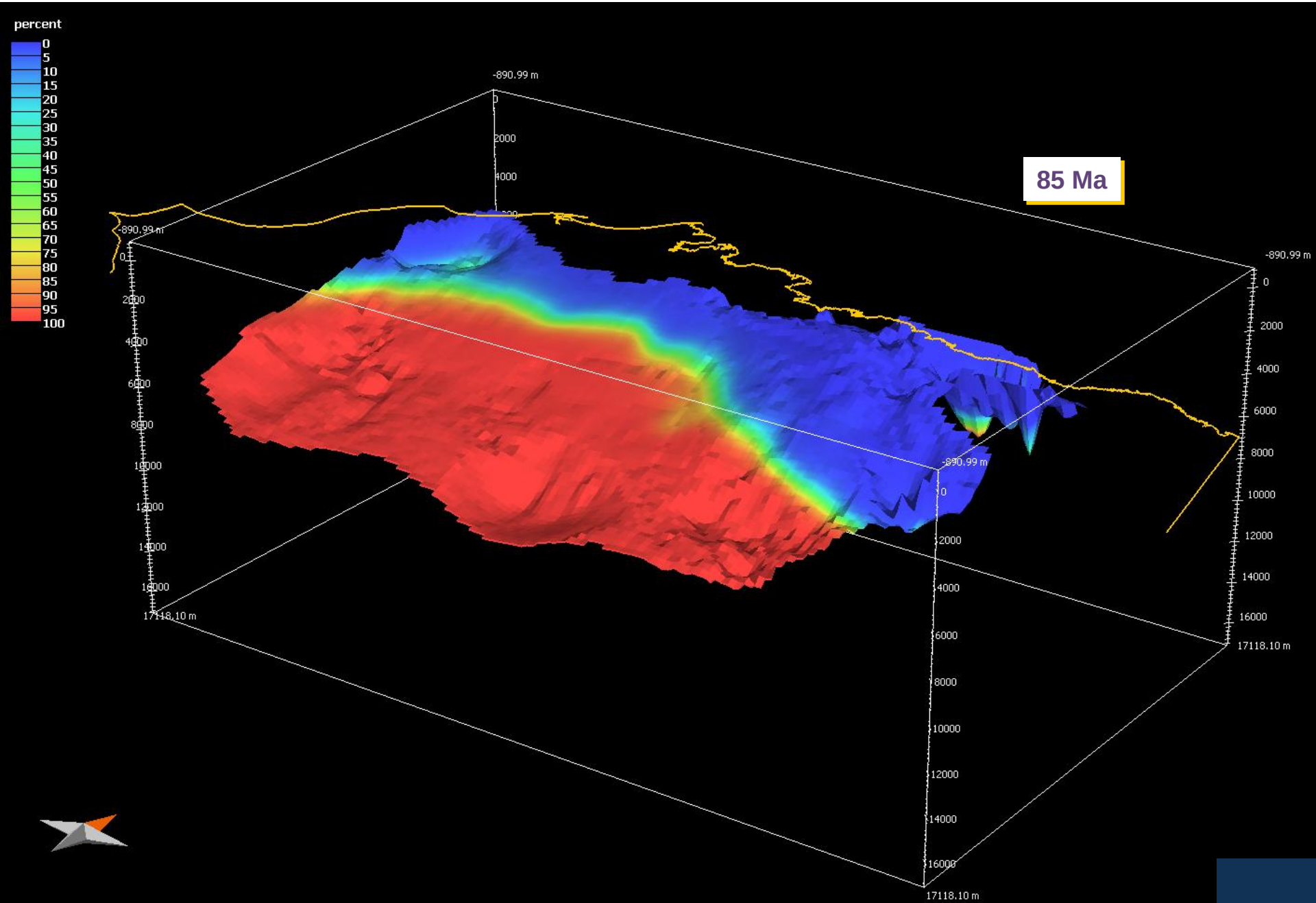
Alaska North Slope - 3D Petroleum Systems Model

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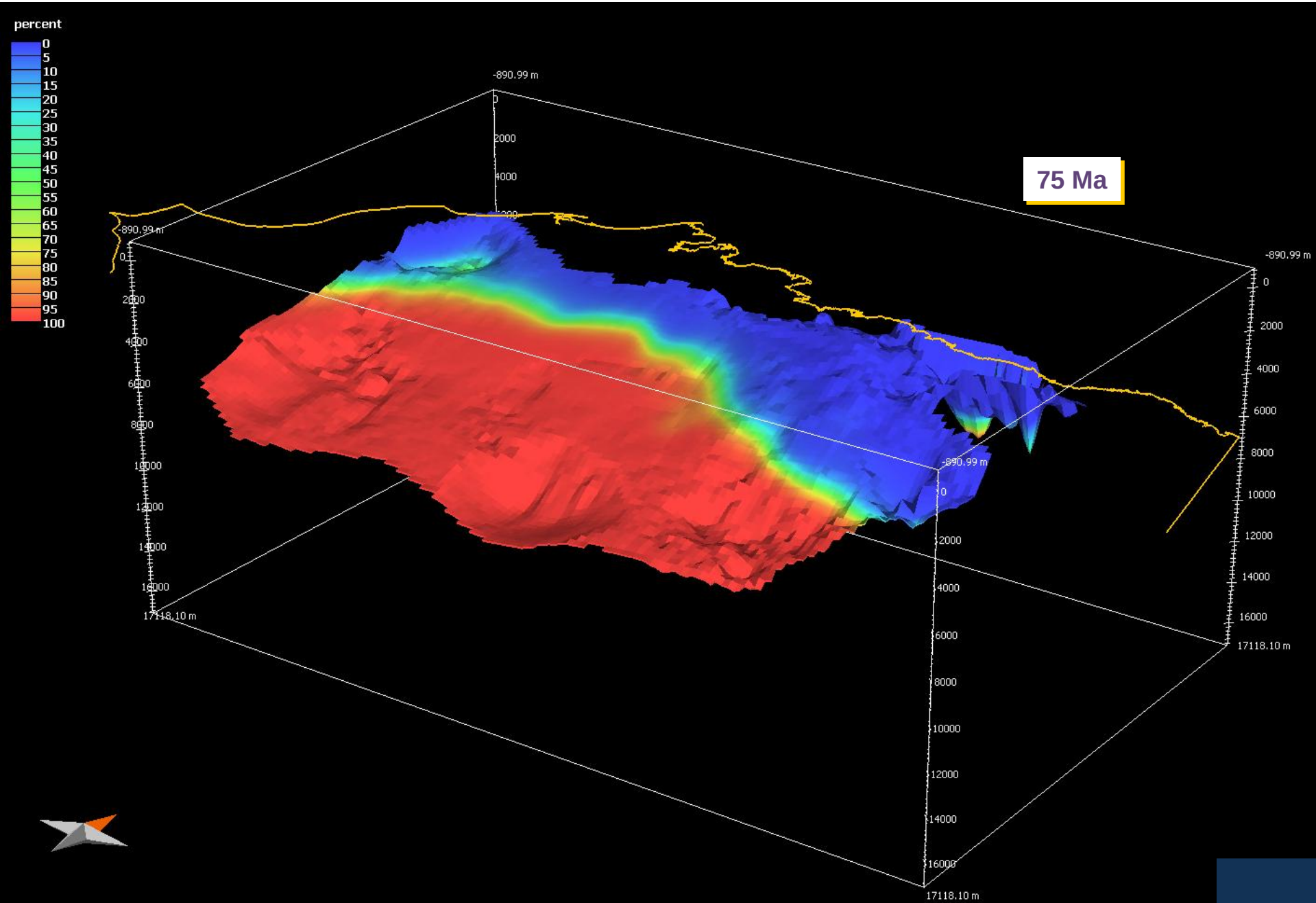
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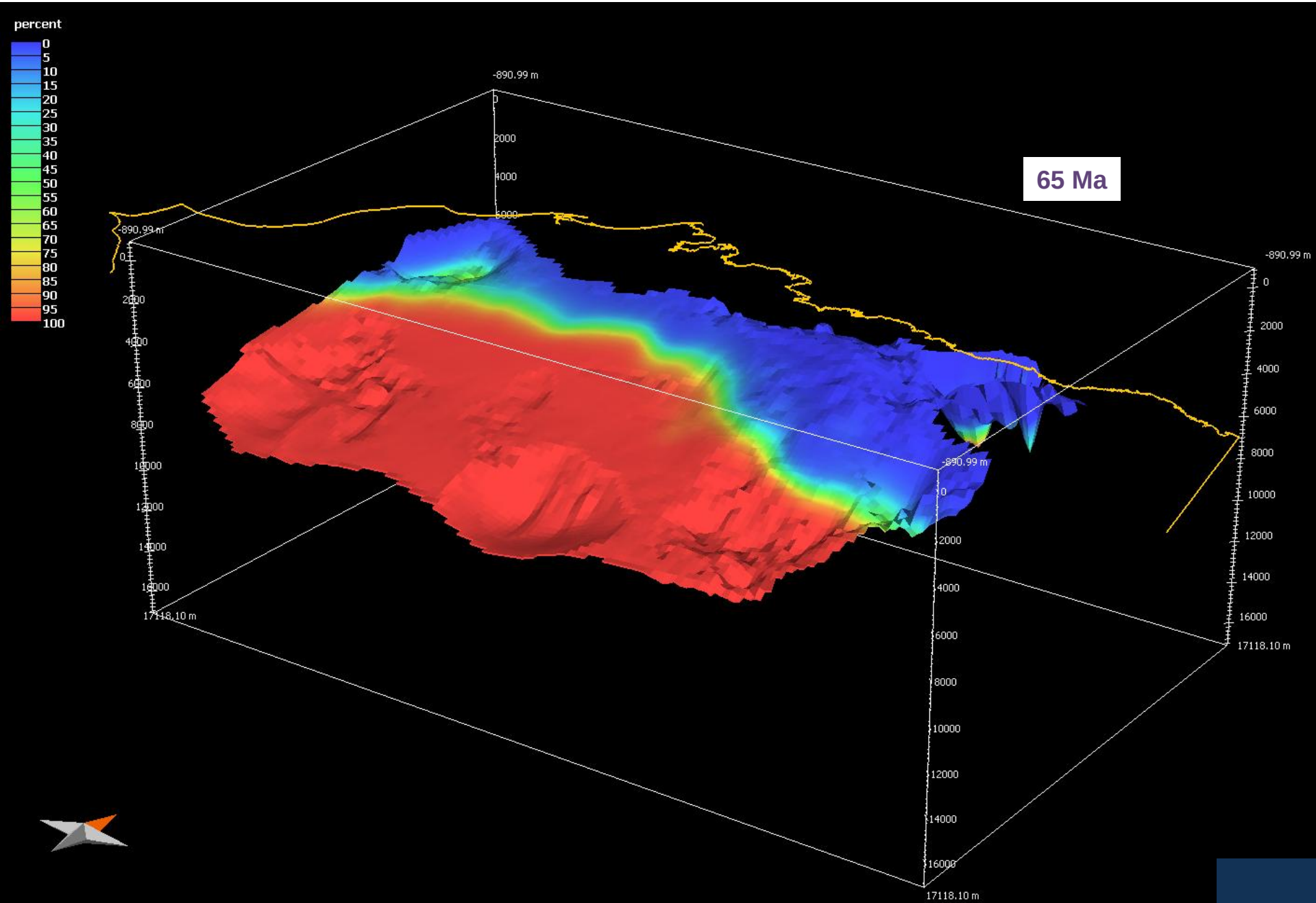
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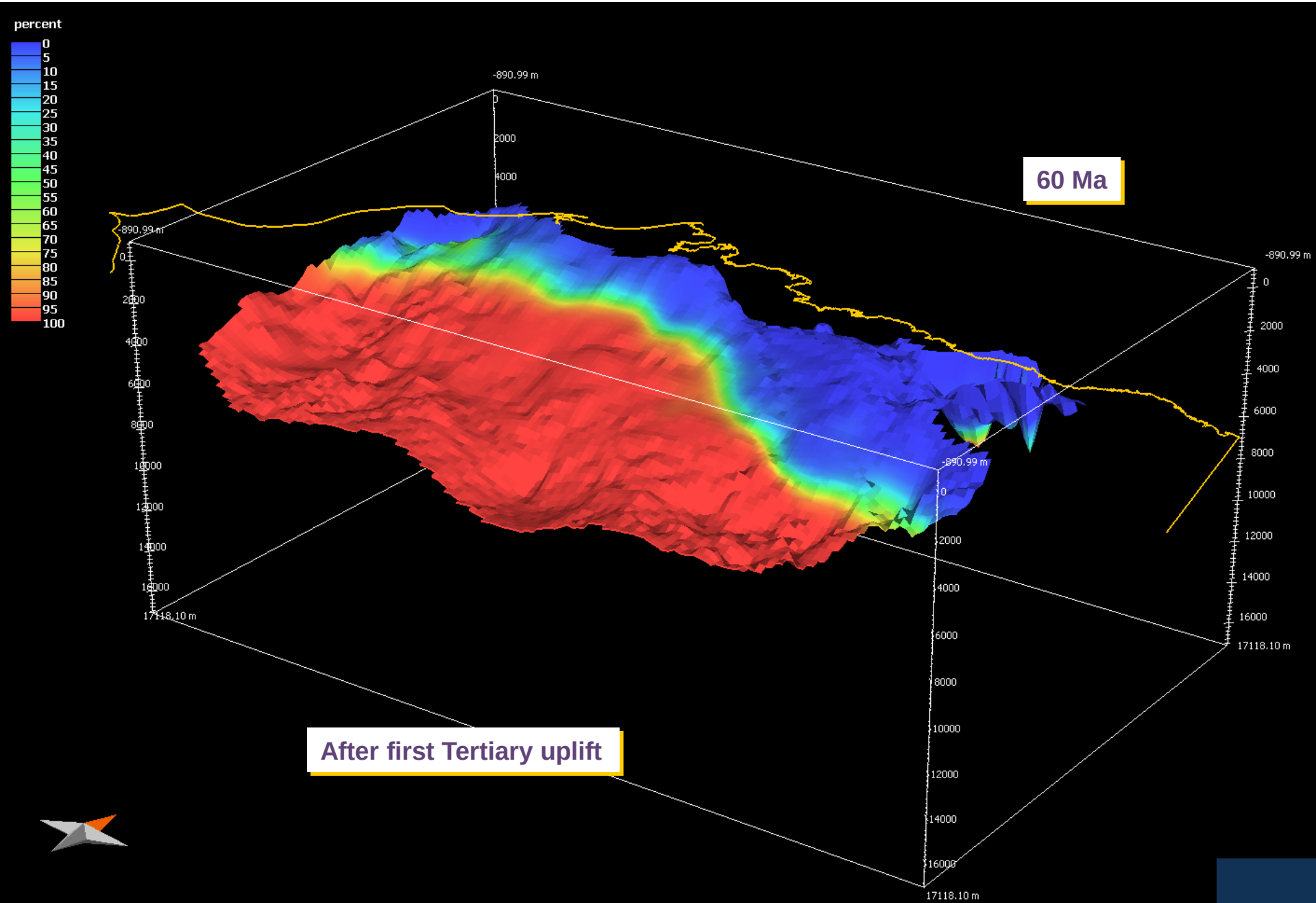
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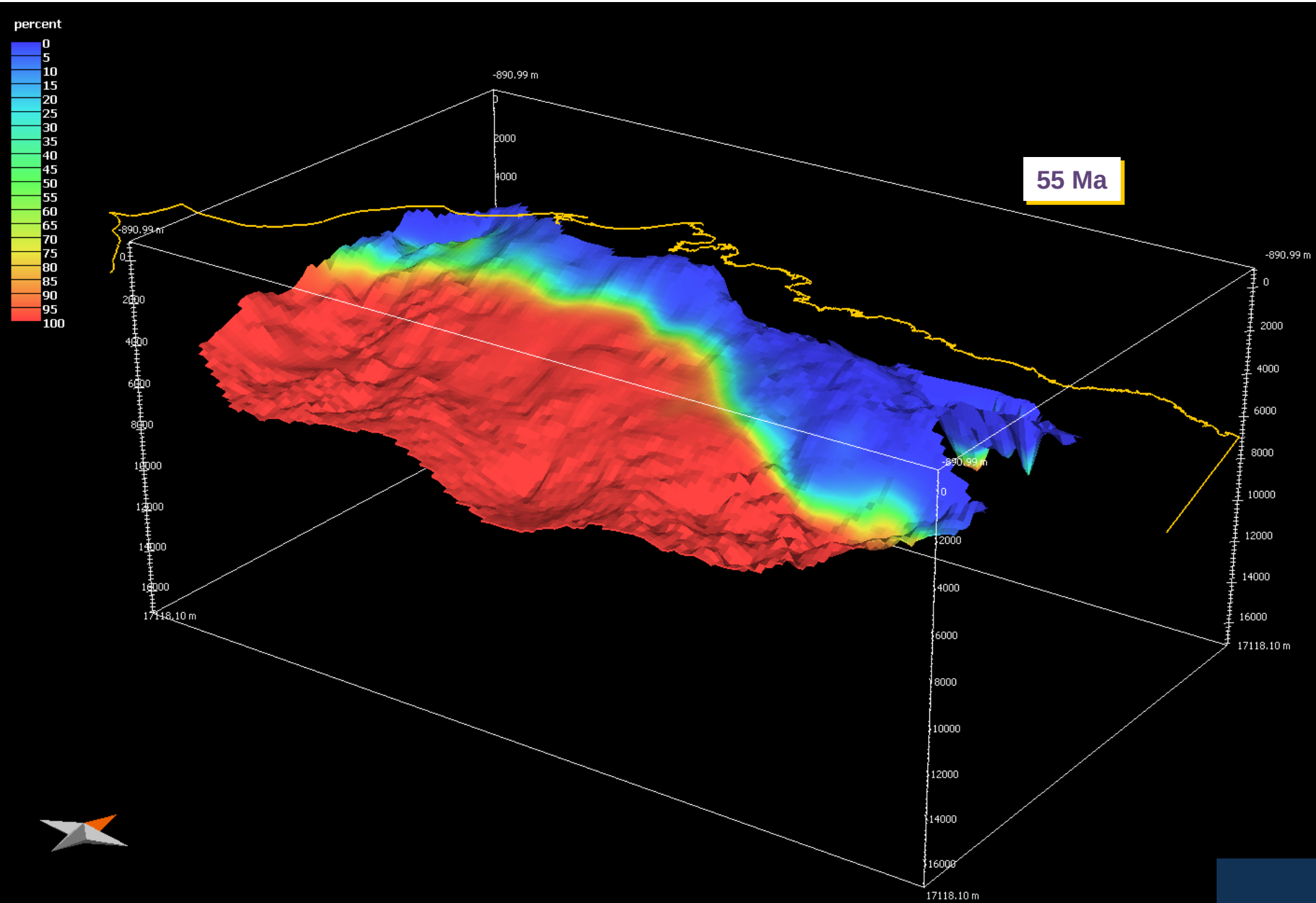
17118.10 m
60 Ma
After first Tertiary uplift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-890.99 m
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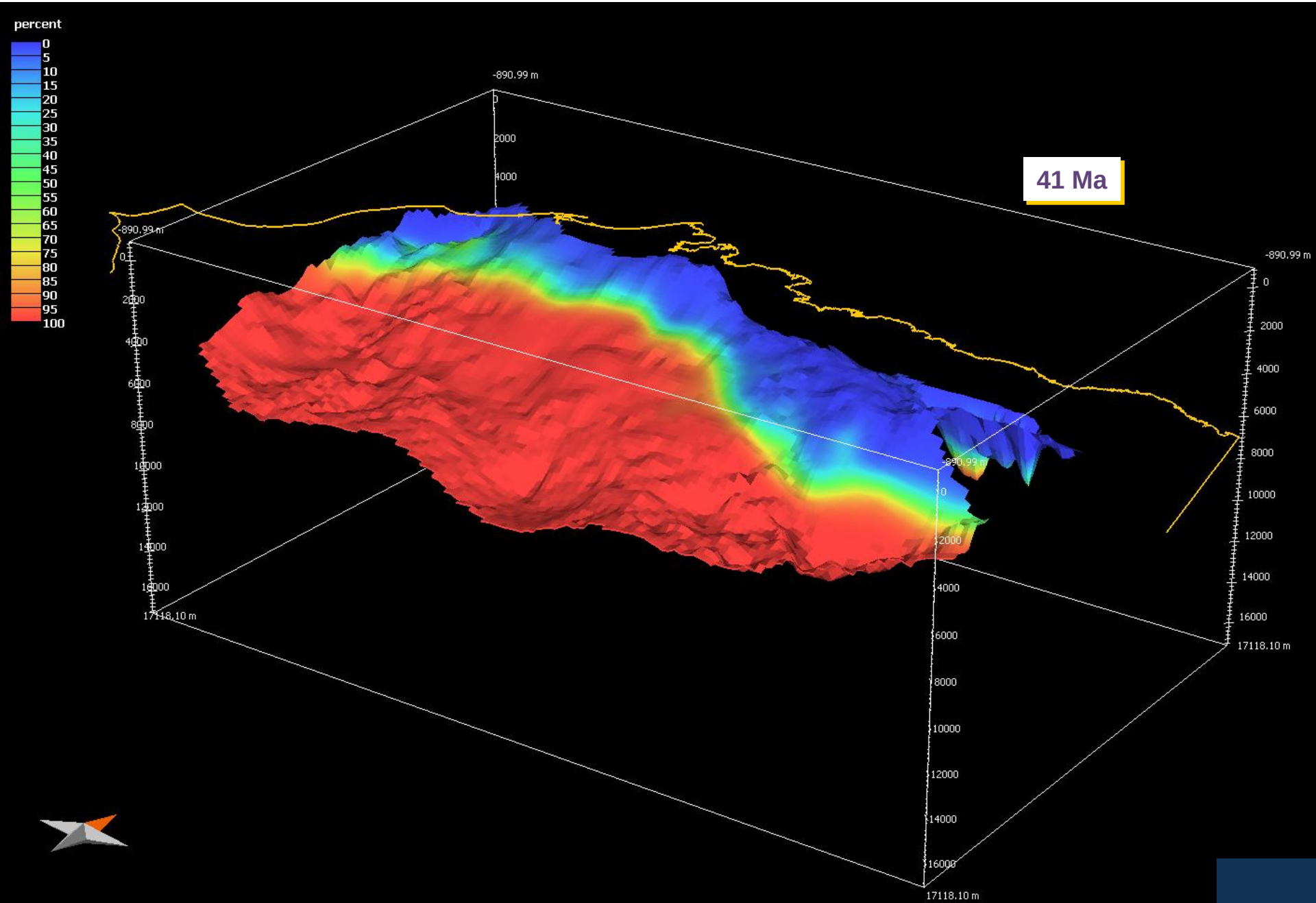
17118.10 m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41 Ma
-890.99 m
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2000
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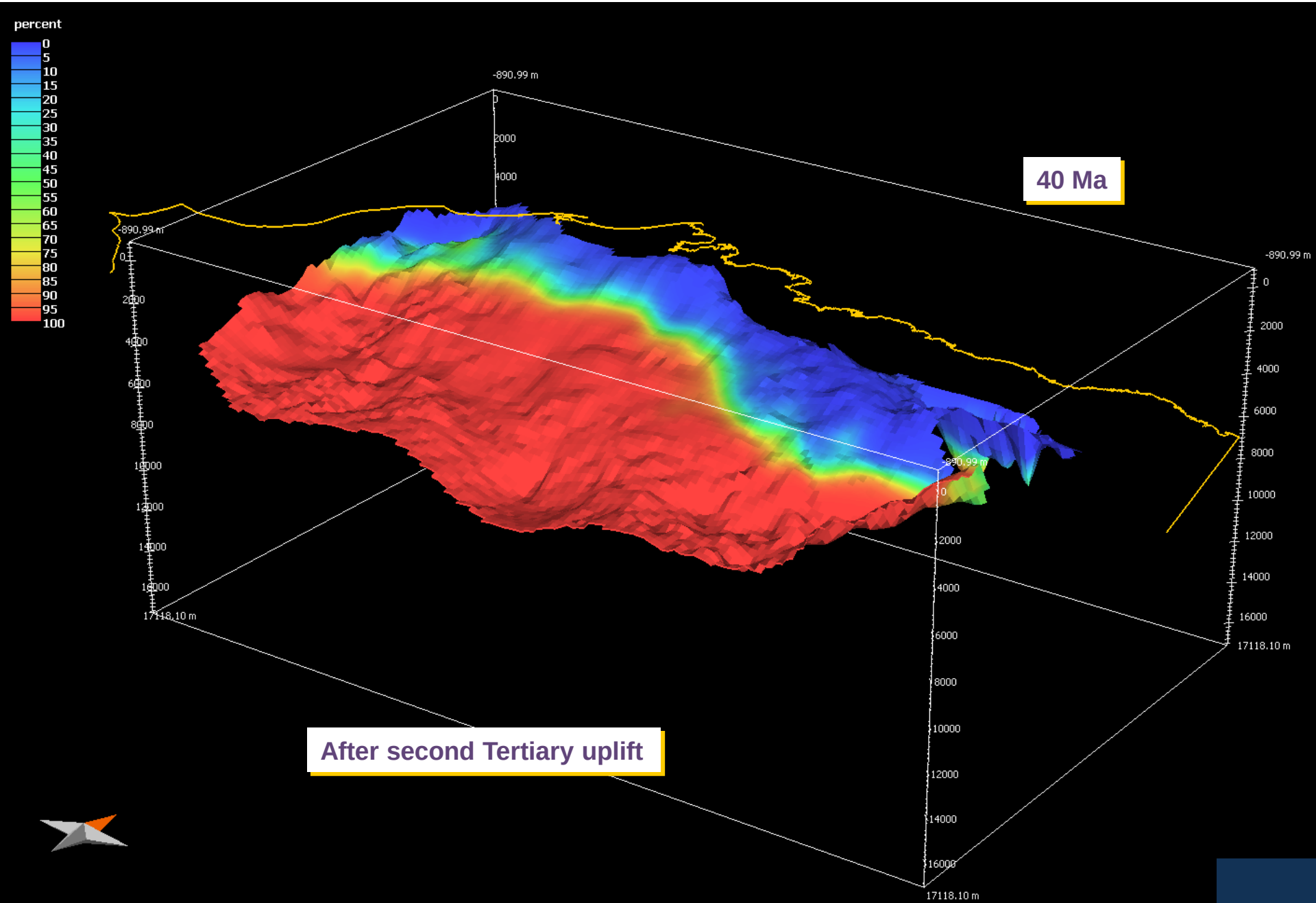
14000
16000
17118.10 m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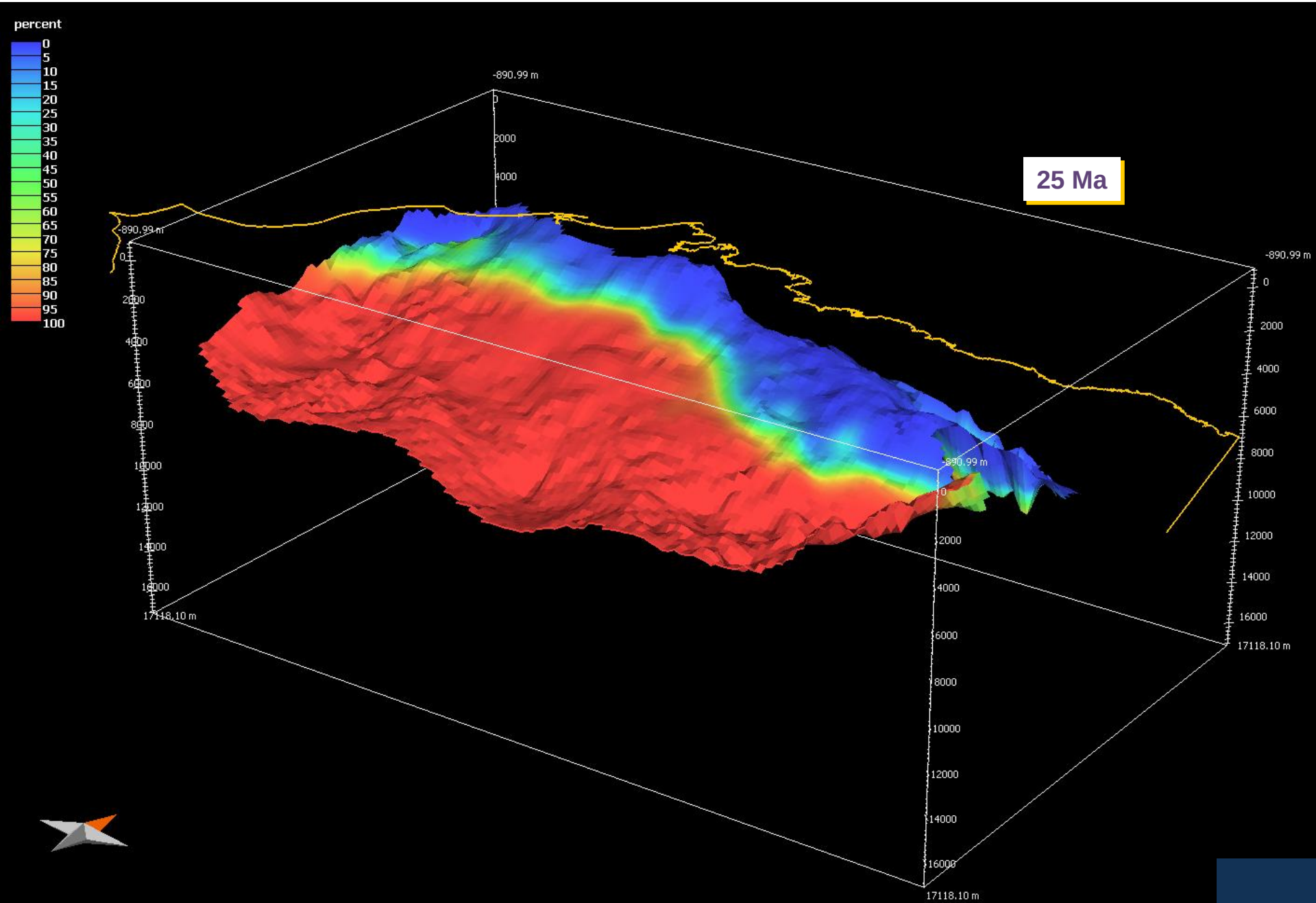
100
40 Ma
After second Tertiary uplift
-890.99 m
17118.10 m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25 Ma
-890.99 m
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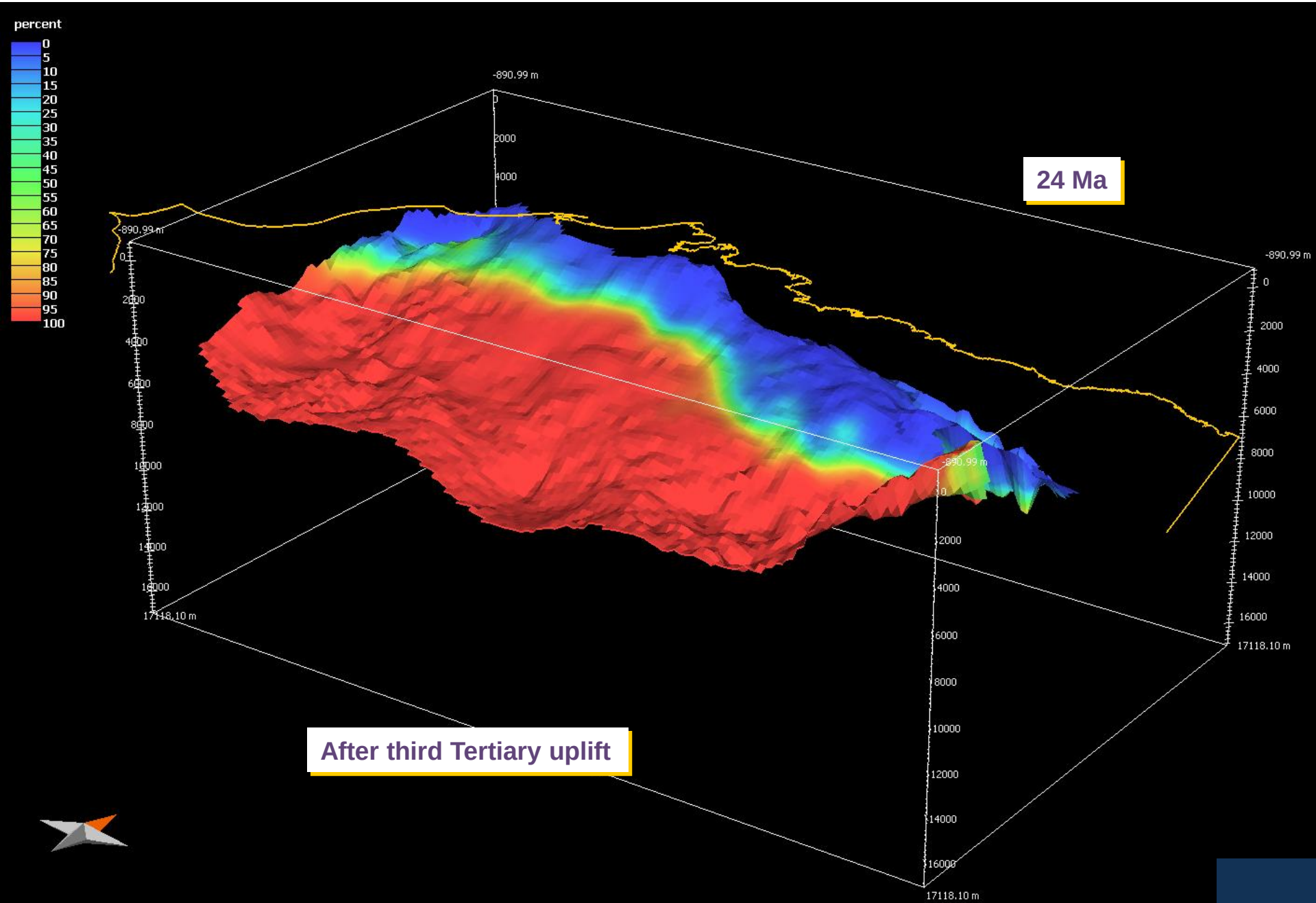
10000
12000
14000
16000
17118.10 m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-890.99 m
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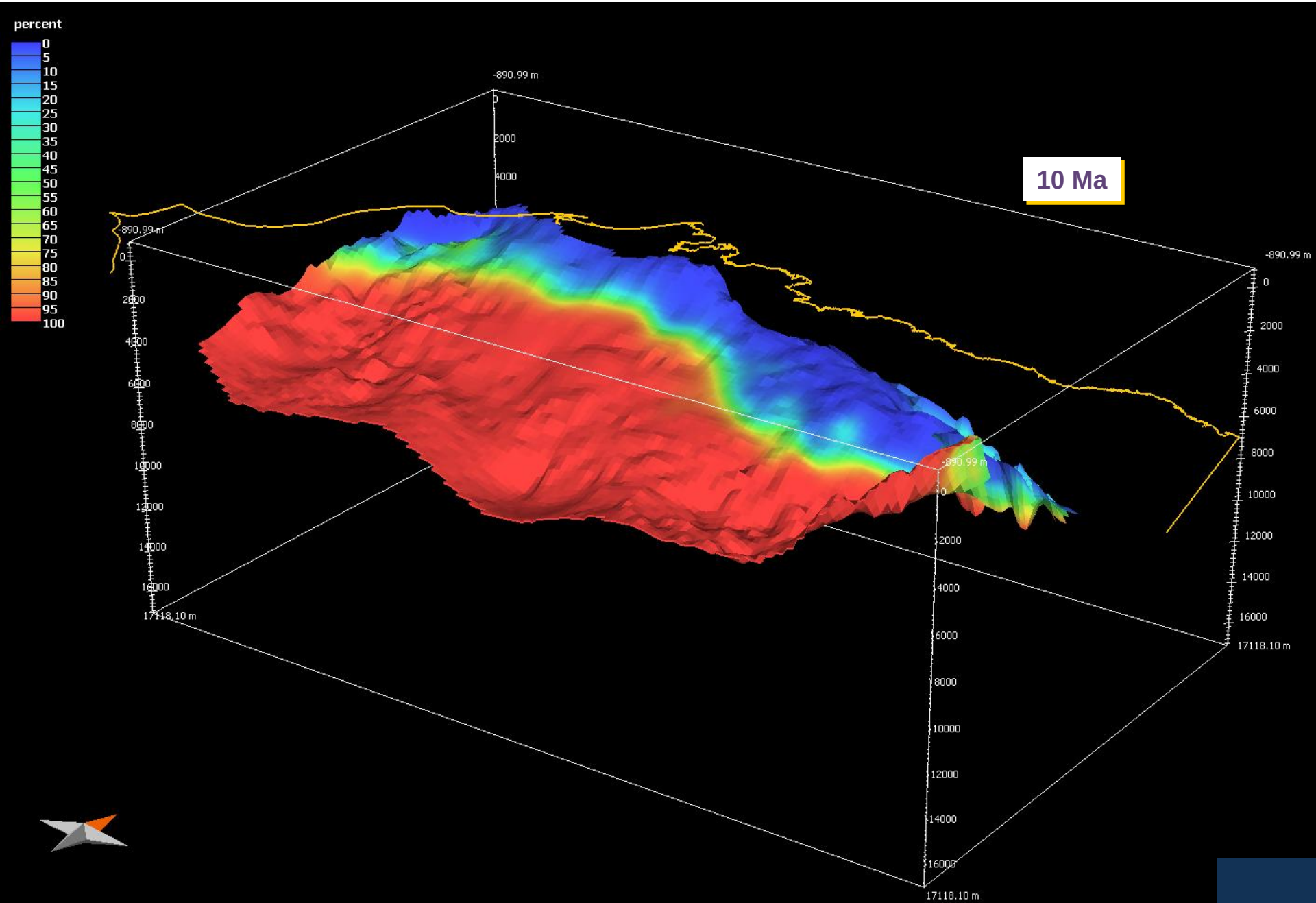
12000
14000
16000
17118.10 m
24 Ma
After third Tertiary uplift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10 Ma
-890.99 m
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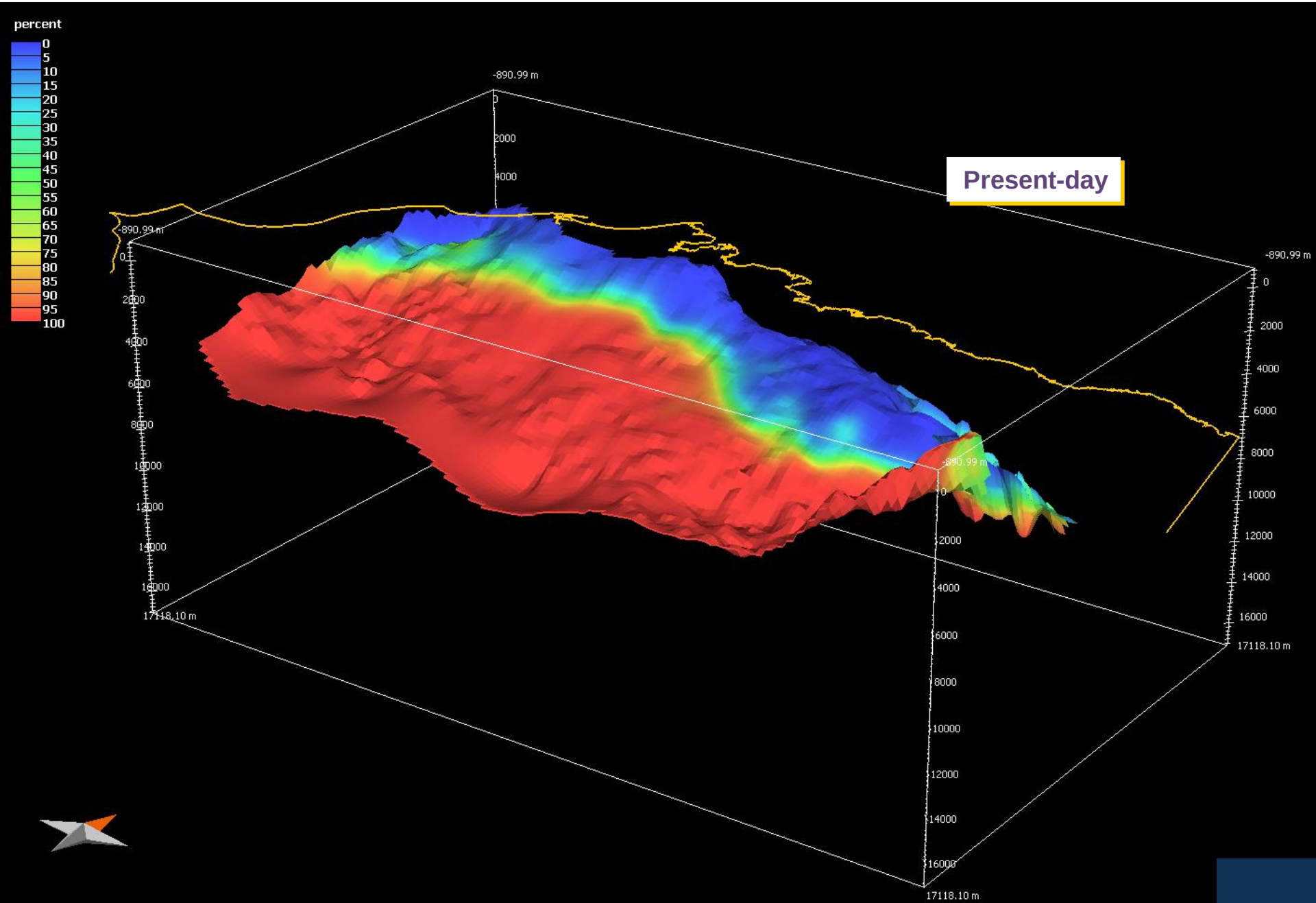
17118.10 m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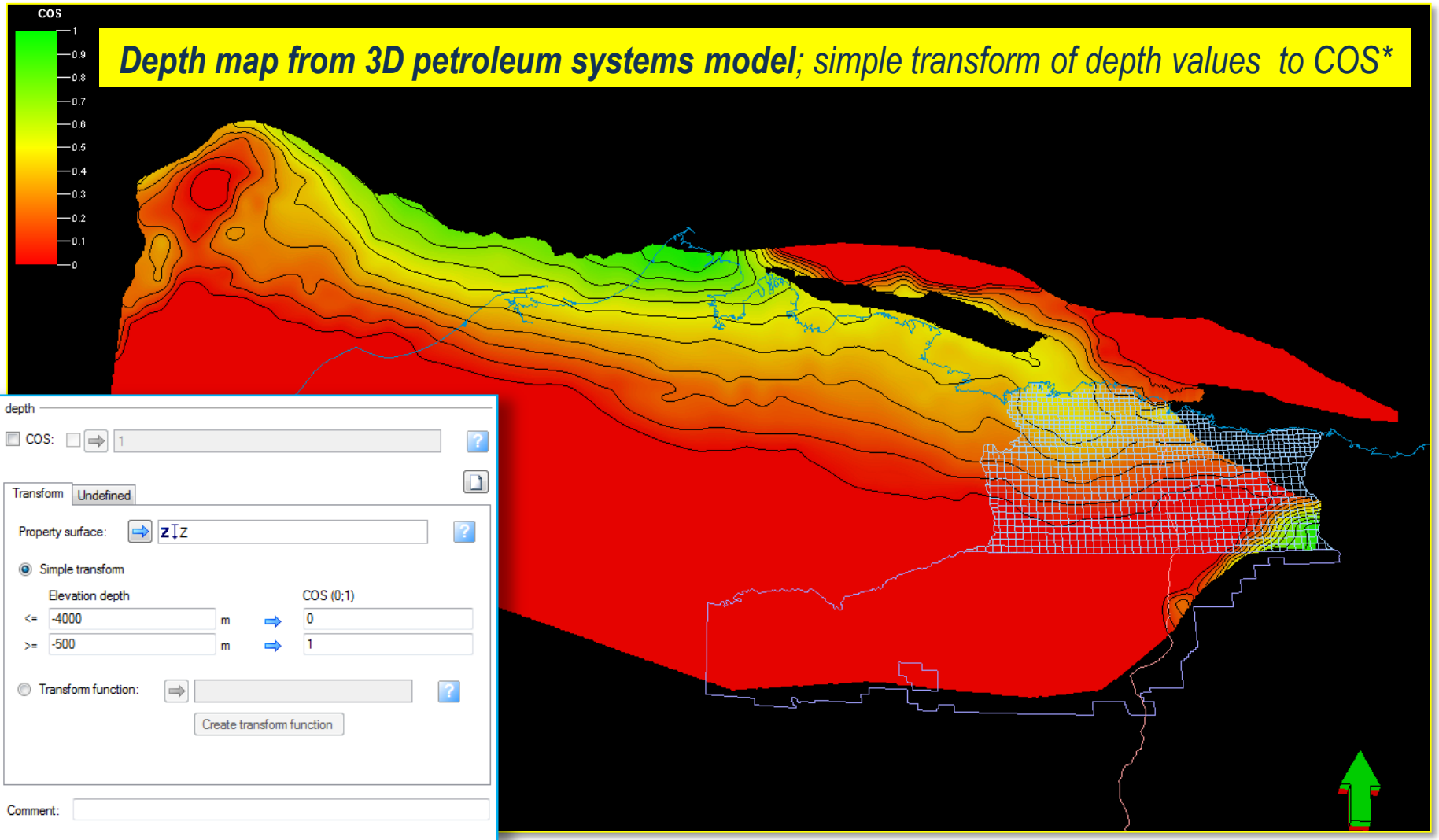
17118.10 m

Play Chance Mapping – COS Depth



depth

COS: 1

Transform | Undefined

Property surface: z↕z

Simple transform

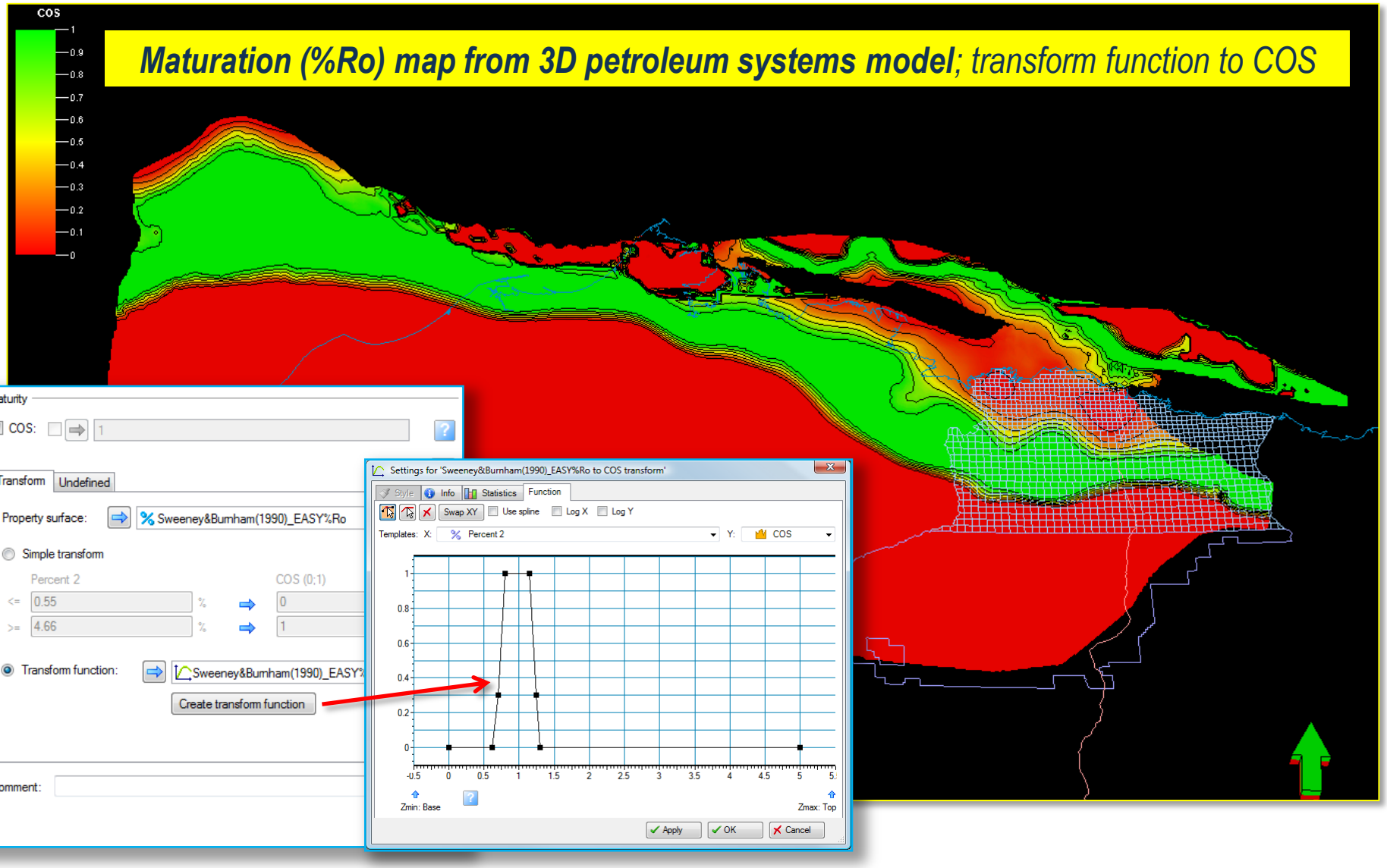
	Elevation depth		COS (0;1)
<=	-4000	m	0
>=	-500	m	1

Transform function:

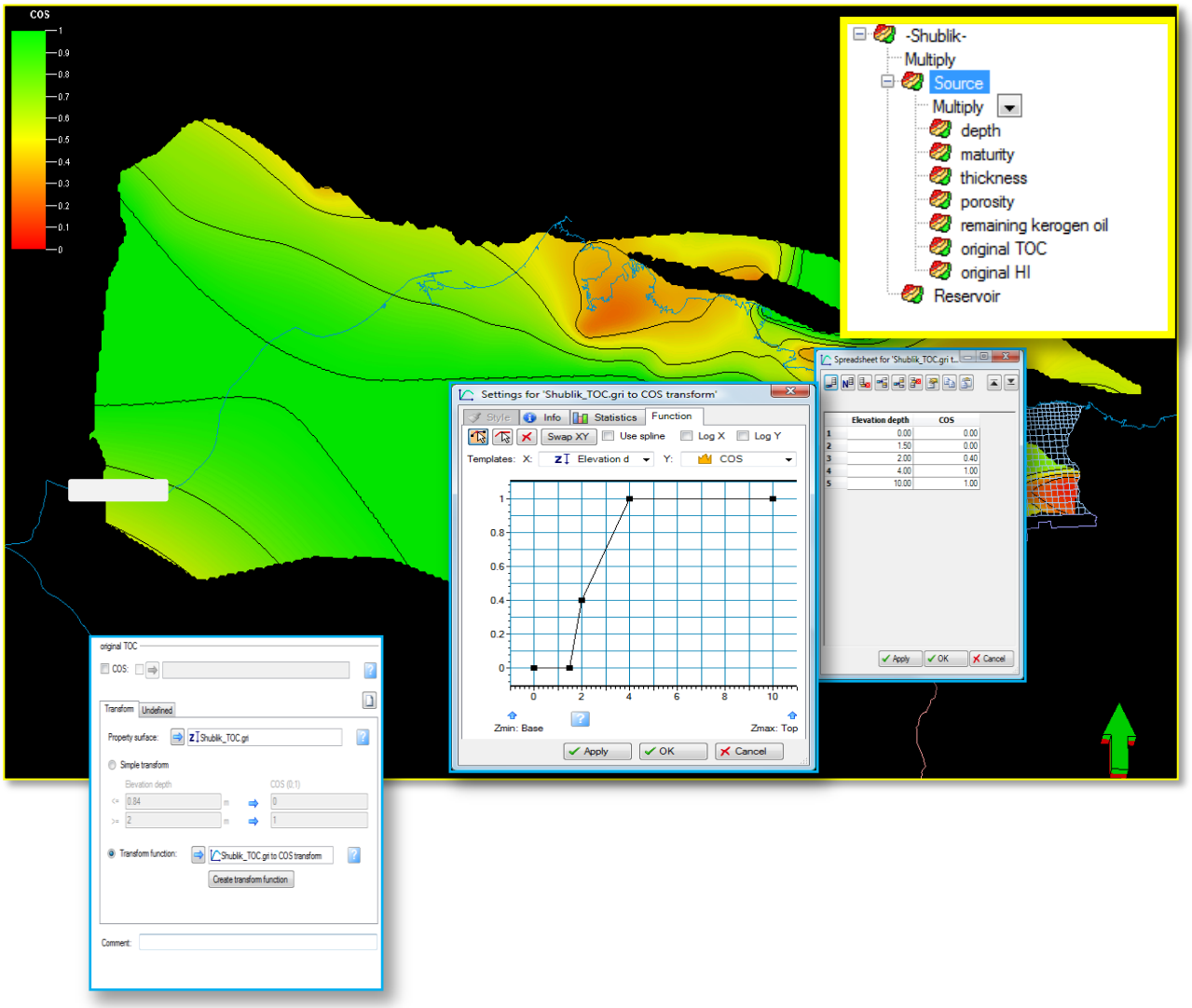
Create transform function

Comment:

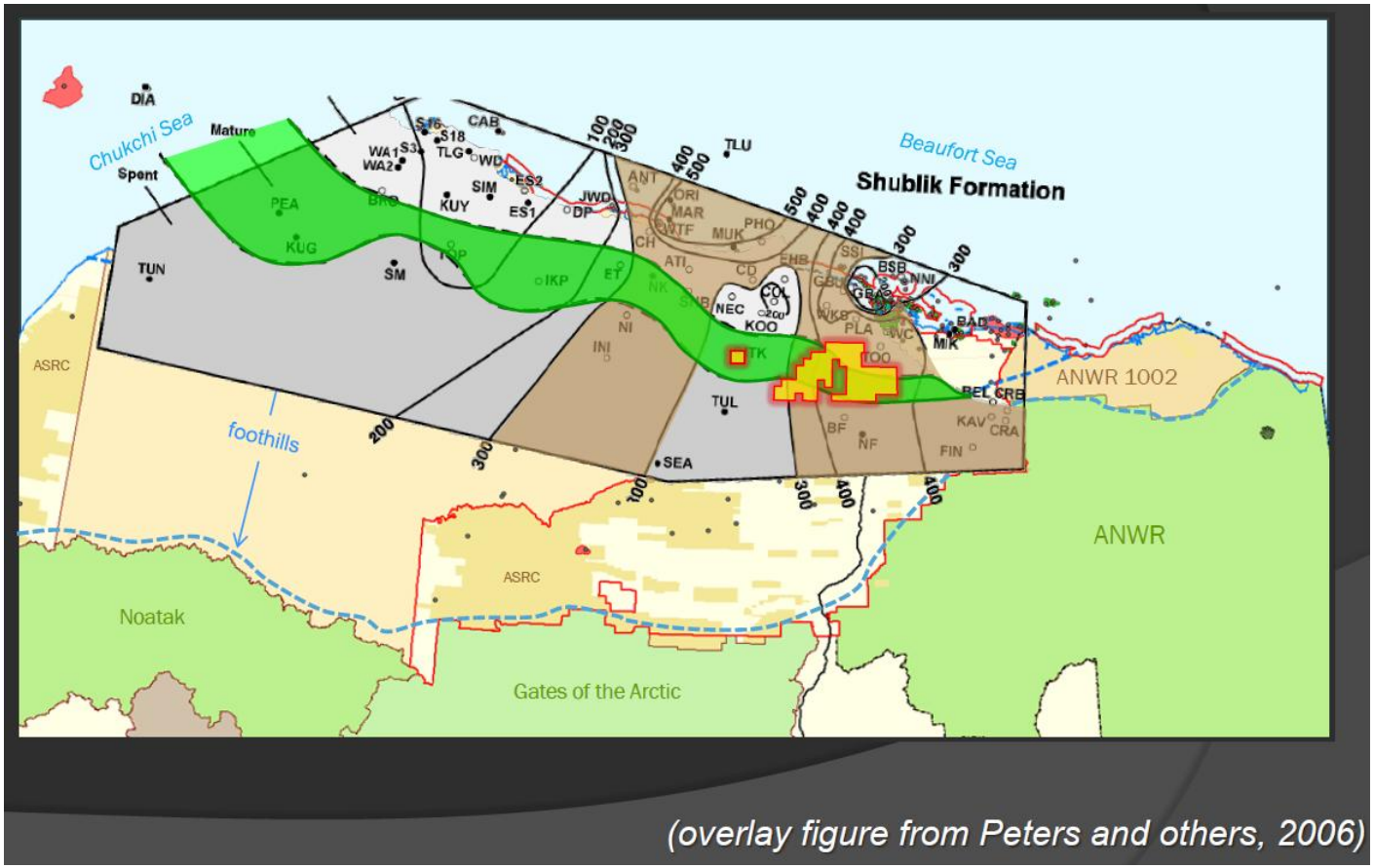
Play Chance Mapping – COS Maturity



Shublick Shale Oil Play, Alaska



Shublick Maturity and Hydrogen Index



(overlay figure from Peters and others, 2006)

From Decker, 2011

Great Bear – Initial Drilling Results

"Duncan said he determined what leases to purchase and where to drill test wells using a model of the North Slope petroleum system developed by Schlumberger … based on science done by the U.S. Geological Survey and Stanford University. The model had proved successful in explaining the mix of oils found in North Slope fields. The model had predicted the locations of "liquids fairways" in the source rocks, and the drilling results so far have substantiated those predictions, Duncan said."

http://www.adn.com/2012/09/22/2636242/great-bear-wants-to-speed-up-shale.html#storylink=cpy

Agenda

- Introduction
  - Understanding geology **and** technology is key
- Exploration tools
  - Wellbore characterization
  - Emerging seismic methods
  - Petroleum system modeling
- Models to improve success
  - Exploration phase – getting the right acreage early in play
    - Data-poor example: Haynesville gas play
    - Data-rich example: Alaska oil play
- Conclusions

Conclusions

- Shale plays rely on finding areas where conventional source rocks may be directly exploited as unconventional reservoirs
- Economic exploitation of shale resource plays requires an understanding of both geology **and** technology
- Petroleum systems modeling provides an integrated framework to estimate resource richness early in the life of unconventional plays
- More work required to investigate stratigraphic variation within and adjacent to source rocks