Shale Oil Potential of the Paris Basin, France*

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Abstract

In the French Paris Basin, most of hydrocarbons are generated in the Liassic Shale interval. Among these Liassic deposits, three source rock intervals are identified in the basin: the Lower Toarcian organic-rich interval ("Schistes Carton"); the Pliensbachian ("Amaltheus Shale"); and the Sinemurian-Hettangian. All are marine shales, with type II kerogen.

Numerous similarities exist between the North American Bakken Shale play, that locally is intensively developed for Shale Oil production, and the Paris Liassic Shale: the high source rock potential with favorable maturation (within the oil window), a very close contact and proximity between the source beds and a potential low porosity tight fractured reservoir, and both basins being cratonic.

Multi-2D basin modeling over the main depocenter of Liassic Shale (east of Paris) helped to understand the source rock maturity evolution through time. Where most deeply buried, maturation started during Lower Cretaceous for Sinemurian source rock, and around mid-Cretaceous for Schistes Carton. Maturity increased until the end of Cretaceous and uplift/erosion of the basin; since then, maturity evolved very little.

Hydrocarbon generation and expulsion history from the source rocks was modeled. HC migration (starting at the end of Cretaceous) is developed upward (Dogger reservoirs) and downward (Triassic reservoirs), faults are important pathways. An evaluation of the amount of hydrocarbons still possibly trapped in source rocks (Shale Oil) was performed. A big part of the generated HC was subsequently expelled; the remaining HC vary from one source rock to another, and also geographically, but is generally in the average of 20-30% of the generated HC.

Based on 2D modeling results, tentative 3D volumetric estimates have been made. The main results taken from 2D modeling were the maturity level of the three source rocks at present day, especially their Transformation Ratio. TR was extrapolated to maps, based on the burial, thickness and structure of each source layer. Then total generated HC were estimated for each of the three source rocks. In total, around 95 bn bbls were generated by the Liassic Shales (Toarcian Schistes Carton being the most prolific source rock).

The use of basin modeling tools supported the new play concept that the Paris Basin is clearly a major area for Shale Oil potential. An exploration strategy is currently developed by Toreador for a proof of play of this unconventional resource.

References

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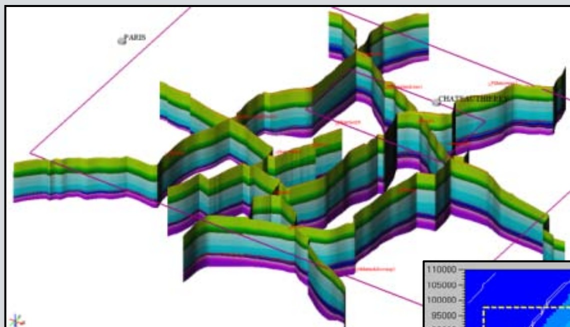
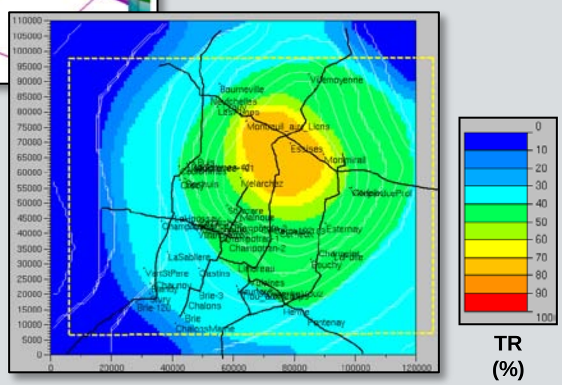
THEME VI: SHALE OIL & GAS CASE STUDIES: THE TOOLBOX ASSETS II (AAPG/EMD)

BASIN MODELING STUDY WITH TEMIS®

SHALE OIL POTENTIAL OF THE PARIS BASIN, FRANCE





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INTRODUCTION

In 2009 Toreador Energy France asked Beicip Franlab to run an evaluation of HC "generated in" and "expelled from" Liassic shales in the Paris Basin.

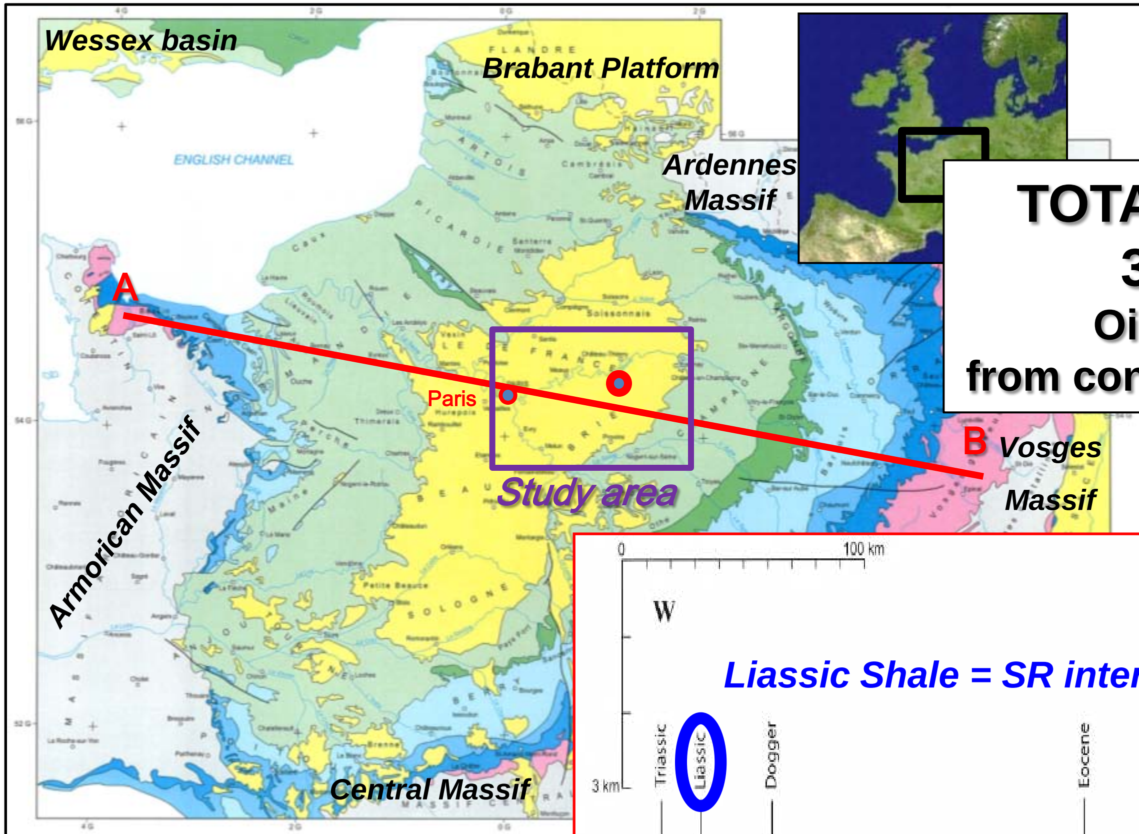
This talk sums up the workflow that was used to estimate from 2D data HC volumes in unconventional resources.

It illustrates how *Basin Modelling* is helpful in HC exploration of unconventional oil resources – even in areas with old available data only.

Overview of the Paris Basin Geology

Is there any shale oil potential in the Paris Basin?

Paris Basin Geology

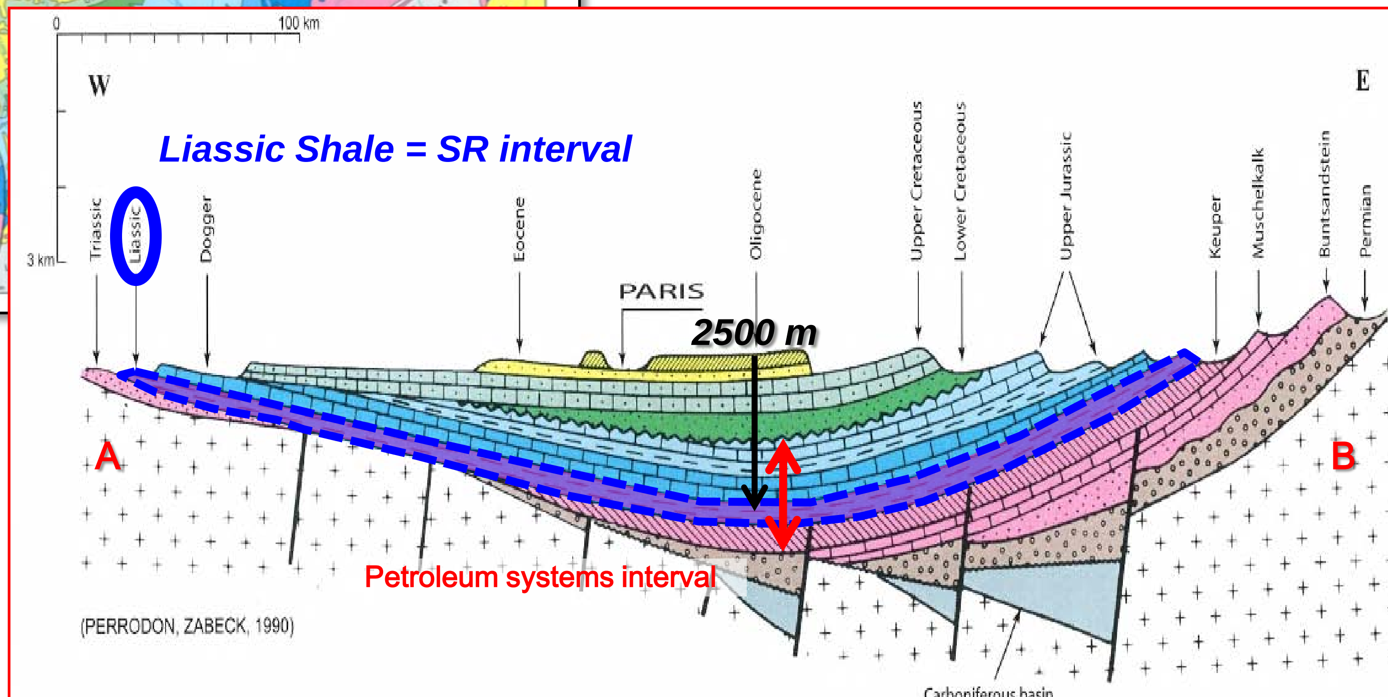


IFP Report, 2002

TOTAL OIL Produced (1958 – 2000)

$33.5 * 10^9$ kg → ~ 0.25 Bbbl

Oil represents 93% of produced HC, from conventional reservoir only, at present day.



Liassic = Lower Jurassic in W. Europe

Unconventional Resources
New Objectives in SR Layers

BeicipFranlab

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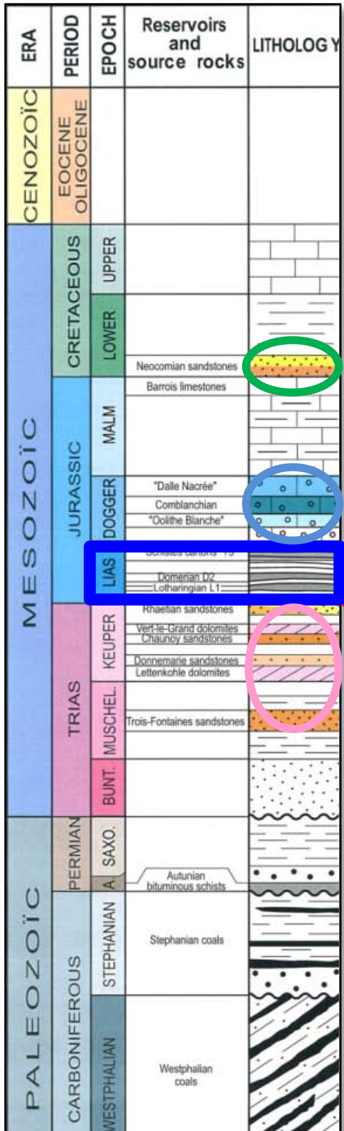


How much HCs remain in the SR interval?

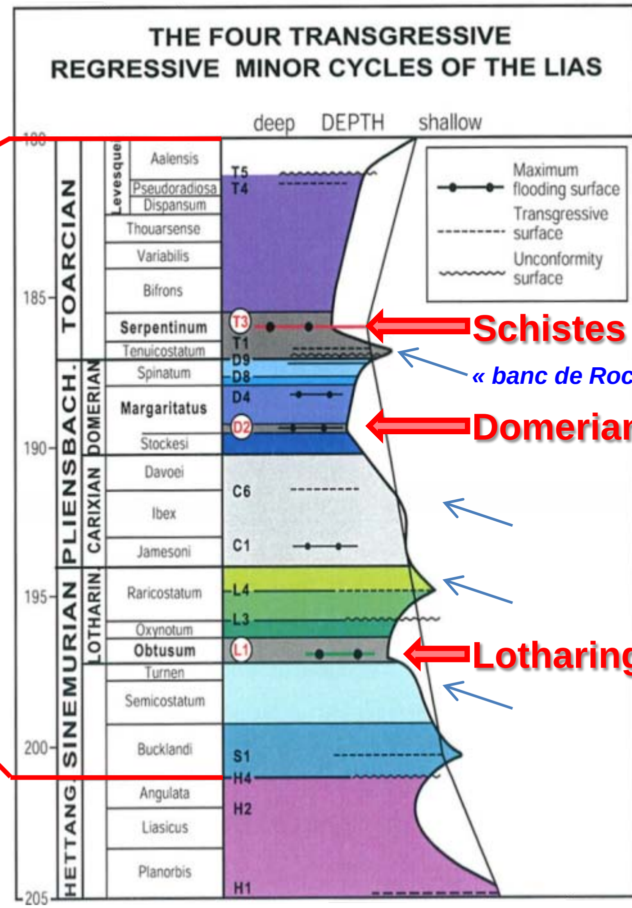
% of Produced Oil

~ 10% *Neocomian*

~ 45% *Dogger*

Liassic SRs

~ 45% *Keuper*



Schistes Carton SR

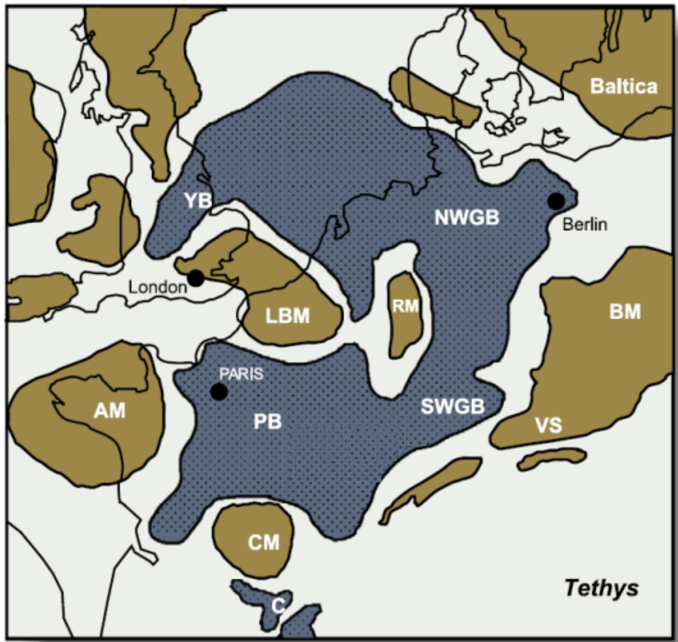
« banc de Roc »

Domerian SR (eq. Amaltheus Shale SR)

Lotharingian – Sinemurian SR

IFP Report, 2002

Focus on the « Schistes Carton » eq. « Posidonia Shale » (2009)



From Frimmel, 2004

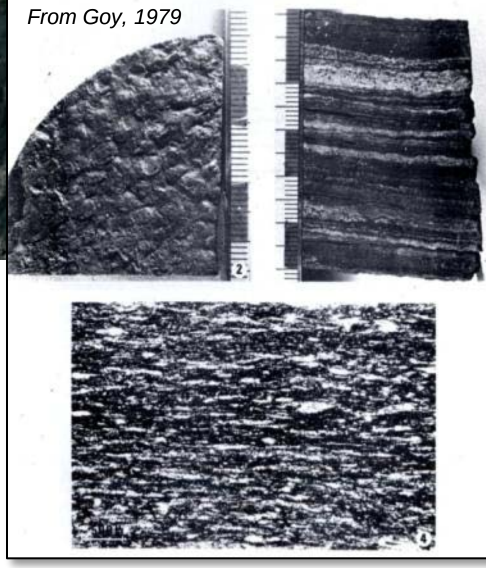
Land areas:
CM: Massif Central,
RM: Rhenish Massif,
AM: Amorikan Massif,
LBM:London-Brabant Massif,
BM: Bohemian Massif,
VS: Vindelizian Swell

Shallow shelf areas

Distribution of bituminous facies in Lower Toarcian:
YB: Yorkshire Basin,
NWGB: NW-German Basin,
SWGB: SW-German Basin,
PB: Paris Basin, C:Chalhac.

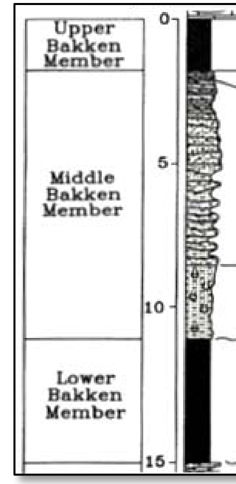
Quarry of Lantenne Vertière (Eastern Paris Basin)

From Goy, 1979



Analogy with the Bakken Shale

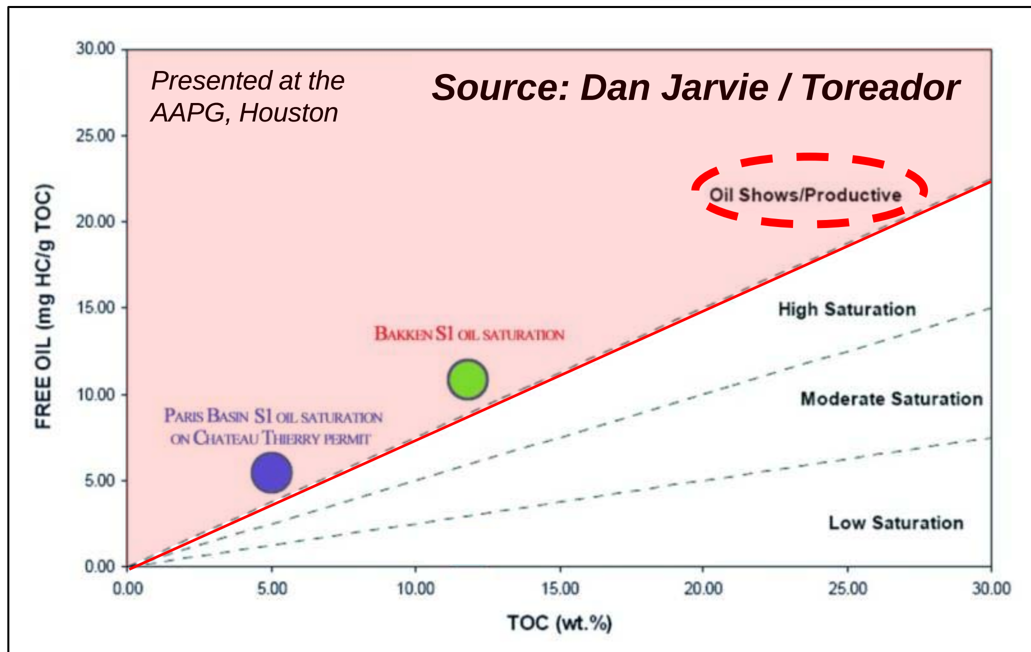
- ✓ Both Williston and Paris Basins are **intracratonic basins**, with a rough circular shape (Williston Basin larger and deeper)
- ✓ **TOC** lower in the Paris Basin (/ 3)
- ✓ SR **thicker** in the Paris Basin (x 2-4)
- ✓ Similar **organic mater** (Type II restricted marine)
- ✓ **Similar maturity** (Tmax = 435 C)
- ✓ **Overpressure** not proven in Liassic SRs
- ✓ **Both basins have an unconventional oil potential** (producing in the Williston Basin)



SR

Bakken Shale unconventional "reservoir"

SR



Available Data for the Temis 2D Study

Only old data is available for the Basin Modelling / Petroleum System Modelling in the Paris Basin.

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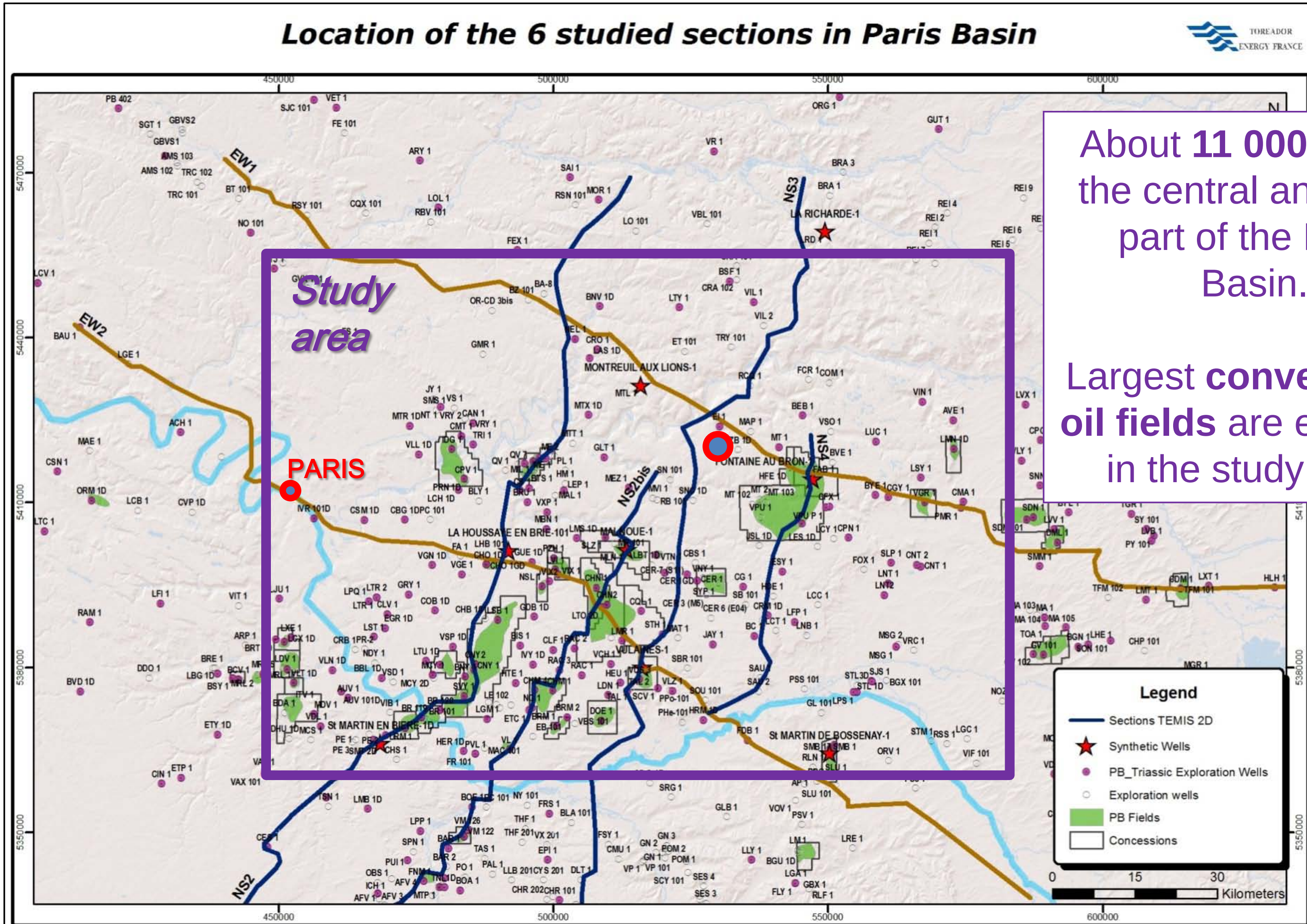
Zoom on the Study Area

Toreador



About **11 000 km²** in the central and deep part of the Paris Basin.

Largest **conventional oil fields** are enclosed in the study area.

From Toreador

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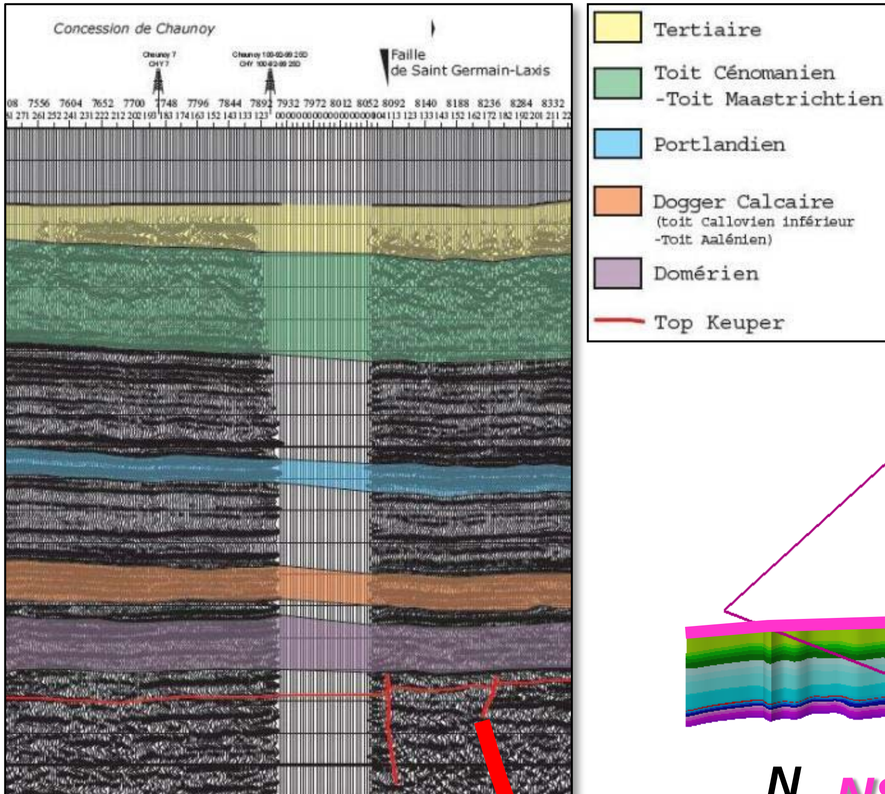
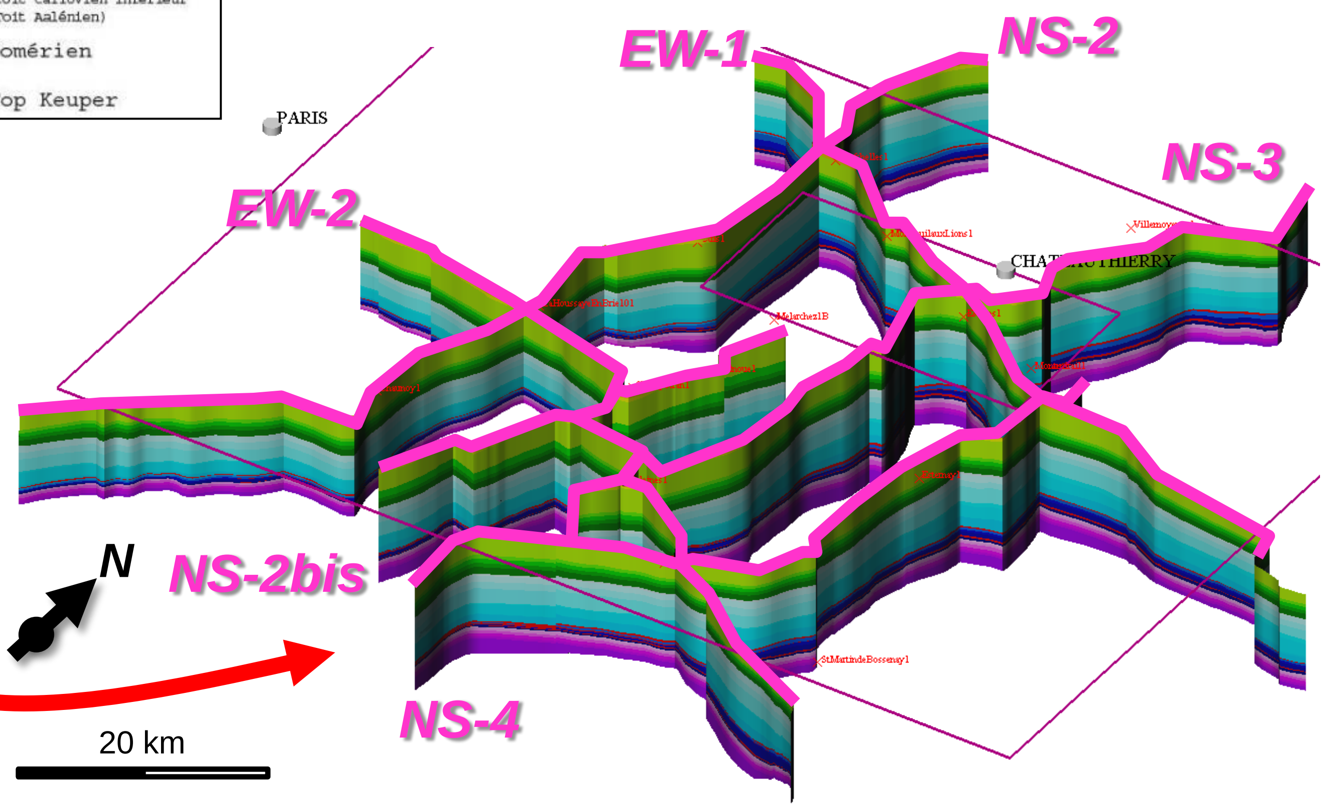
Available Data for the Definition of Unconventional Resources

→ **Old regional seismic lines** (reprocessed in 2007).
→ **Digitalized and slightly corrected.**
→ **Time to Depth conversion done.**
→ **6 SECTIONS:**





Stratigraphic model in Temis 2D

Available Data for the Definition of Unconventional Resources

- **BRGM and IFP Atlases, academic publications**

  - Structural maps (depth and/or thickness maps – regional scale)
  - Sedimentological model and lithology/facies maps (regional scale)
  - Source rocks characteristics (RockEval, kinetics, distribution)
  - Concepts on petroleum systems

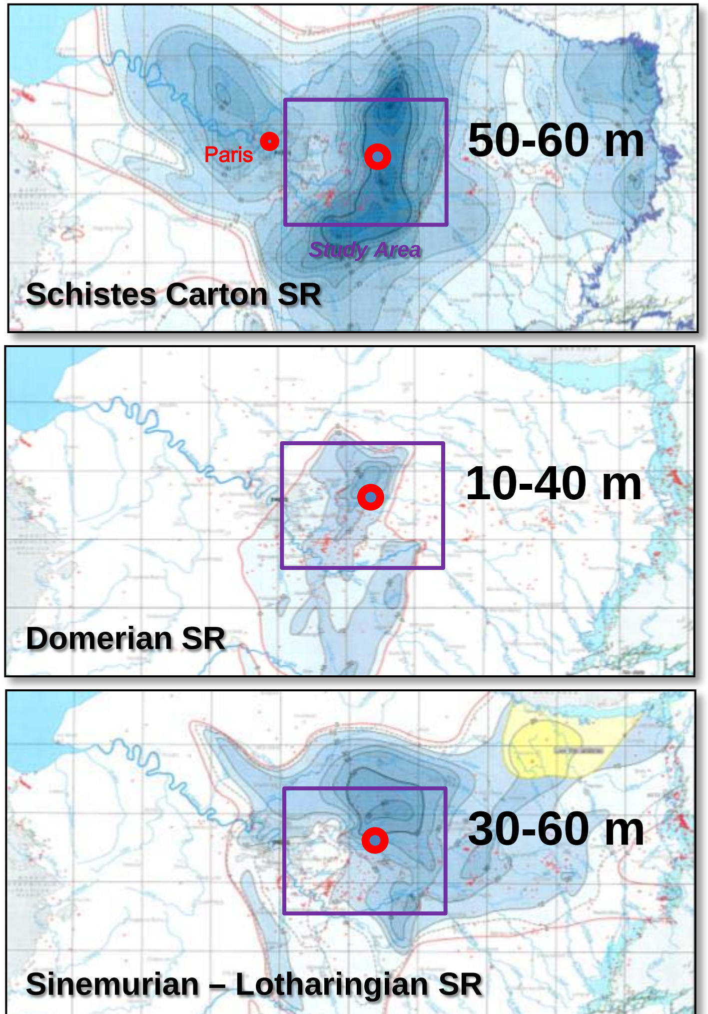
- **Well Data**

  - Stratigraphy and lithology
  - Petrophysical data
  - Calibration data (temperature, pressure,… more than 20 wells used)

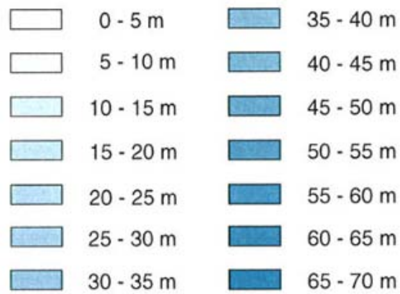
Focus on SR maps
(effective thickness and TOC)

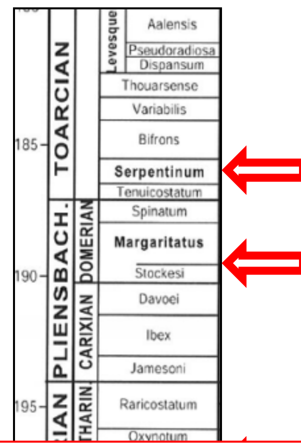
- **Data on Source Rocks (IFP Atlas)**

IFP Atlas, 2002



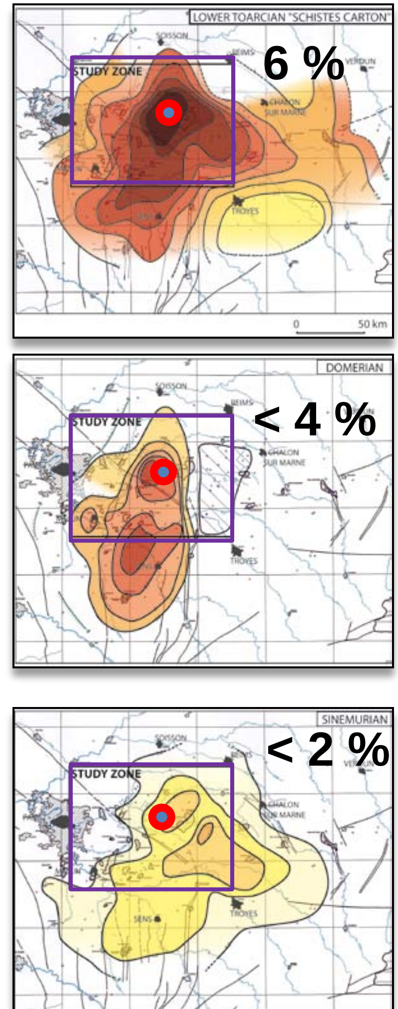
Liassic SRs thickness

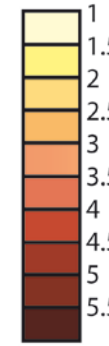




Data on SR layers is highly reliable
hundreds of wells have been used as control points

IFP Atlas, 1996





(at present day)

Liassic SRs TOC

Temis 2D Study Paris Basin

Building of 2D Basin Models

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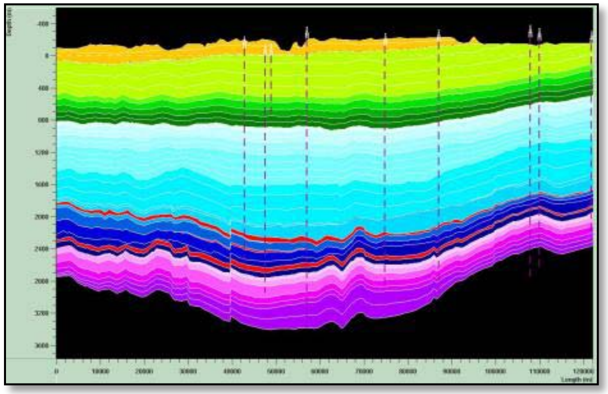
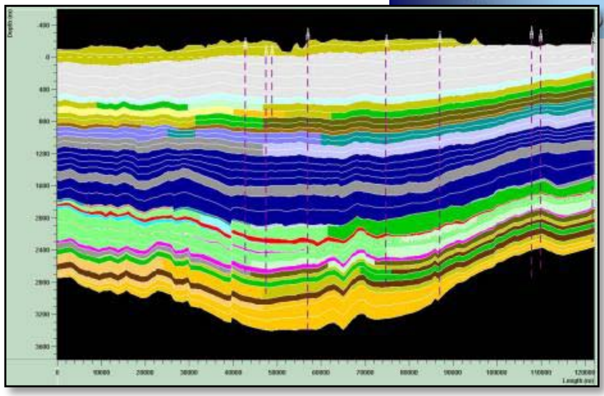
Workflow with Temis 2D®



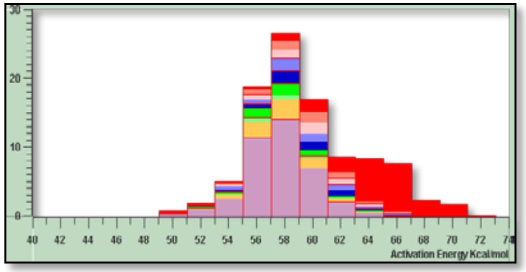
Structure and Stratigraphy
(2D seismic lines)

Geological Environment
- ✓ Tectonic evolution
- ✓ Paleobathymetry
- ✓ Surface paleo temperature
- ✓ Bottom paleo heat flow

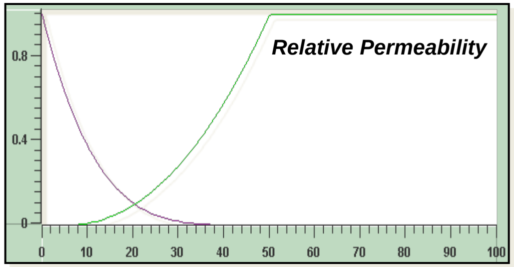


Facies Distribution
(“Lithologies”)

TEMIS



Source Rocks and Kerogen
(Geochemistry and PVT behavior)



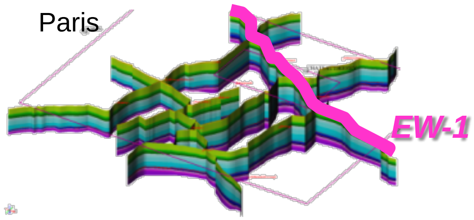
Petrophysical Behavior

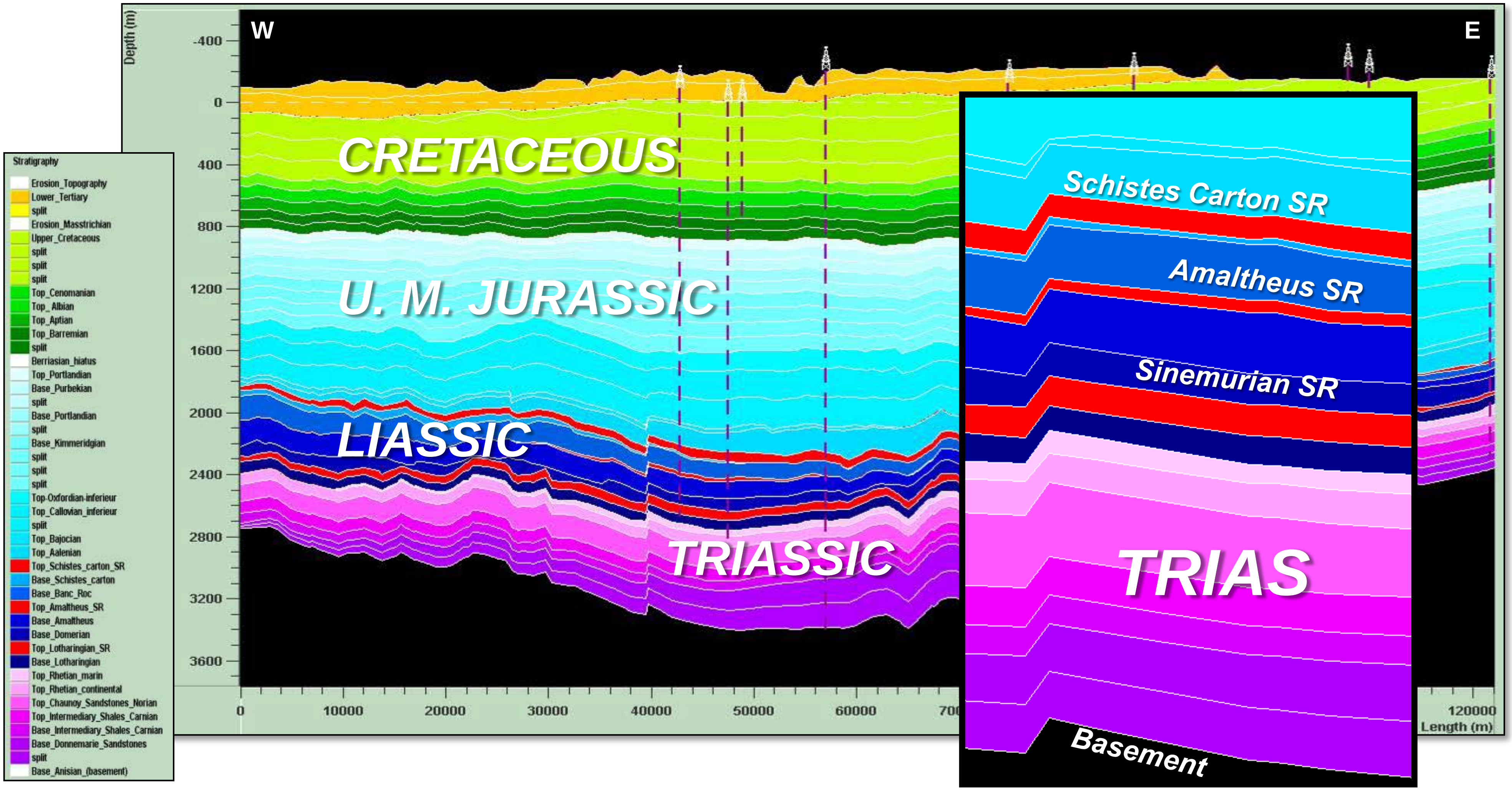
NUMERICAL SIMULATIONS

- ➢ Petrophysical properties
- ➢ Source rock maturity
- ➢ HC expulsion and migration
- ➢ **Evolution through time / timing**

Calibration data
Well Temperature
Well Pressure
HCs Volumes
etc.

TEMIS 2D Sections – Stratigraphy
Section EW-1





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HC Expulsion Modelling
Darcy Law

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How Temis calculates the amount of generated HCs that migrate out of SRs layers?…

Intrinsic permeability K

Relative permeability phase i

$$U_i = -\frac{Kkr_i}{\mu_i}\left(\mathrm{grad}(P-\rho_w g z) + \mathrm{grad}(P_c) - (\rho_w-\rho_i)g\,\mathrm{grad}(Z)\right)$$

Viscosity phase i

hydrodynamism

capillarity

buoyancy

Relates the flow rate Ui of phase i to the different driving forces.

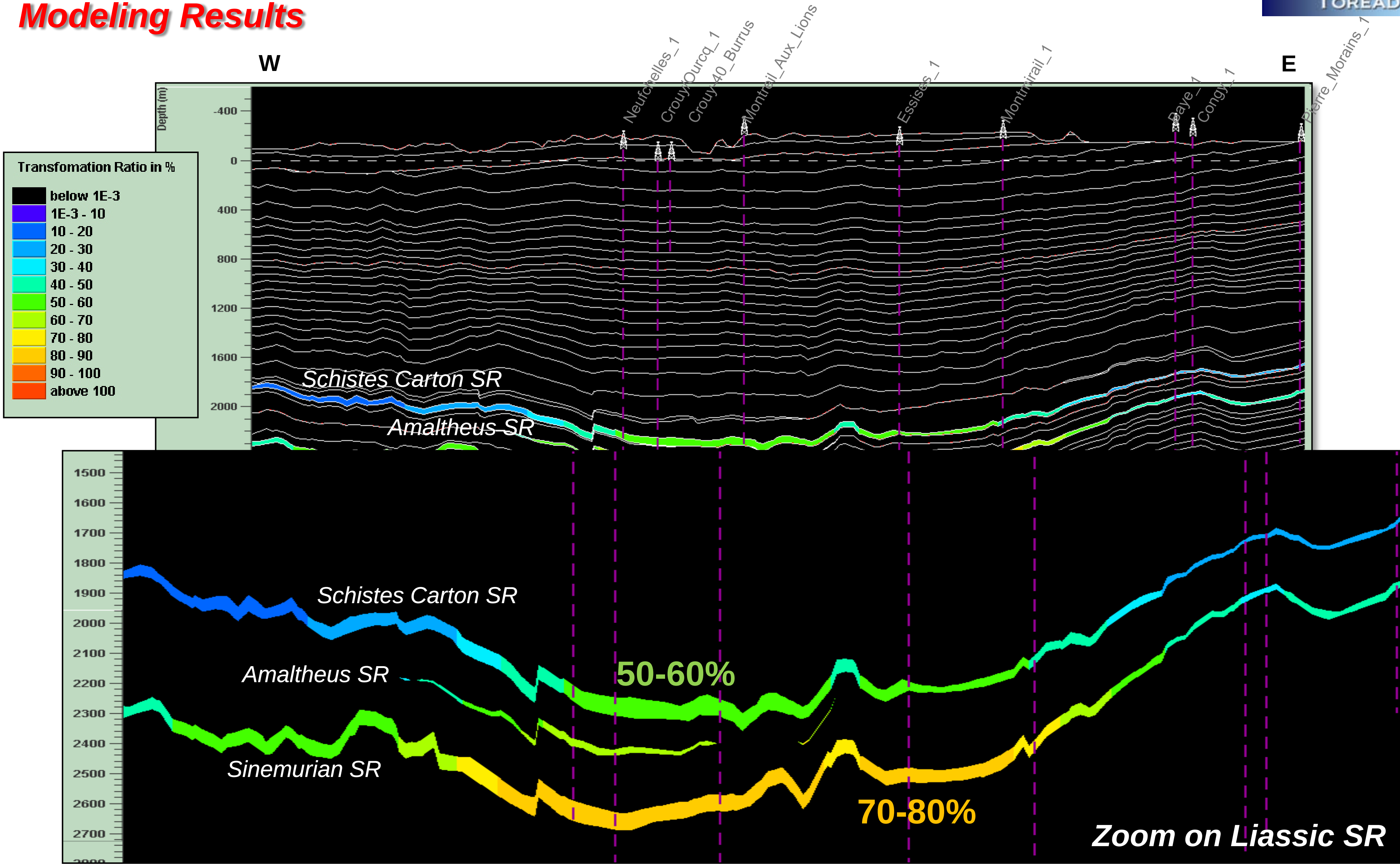
(calculation of HCs and water movements within the porous media)

Temis 2D results

SR Maturity Modelling
HC Expulsion Modelling

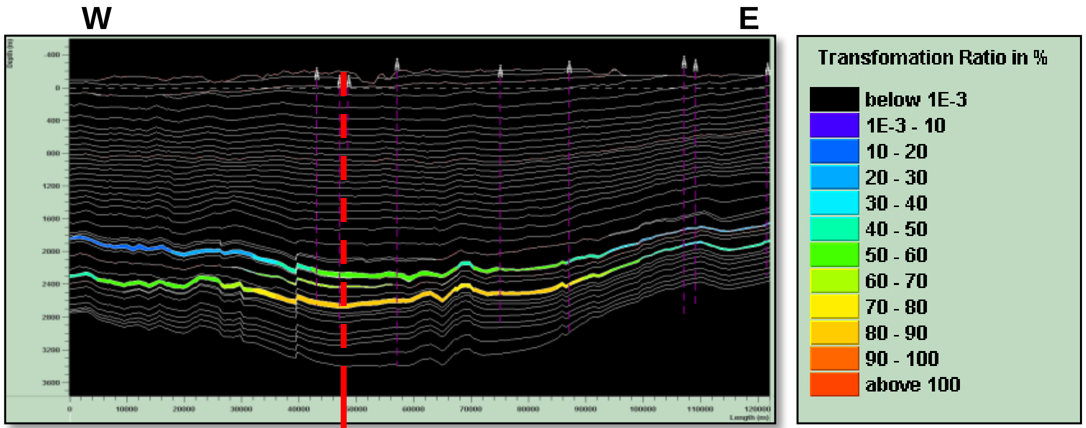
Source Rock Maturity (TR)
Section EW-1

Modeling Results

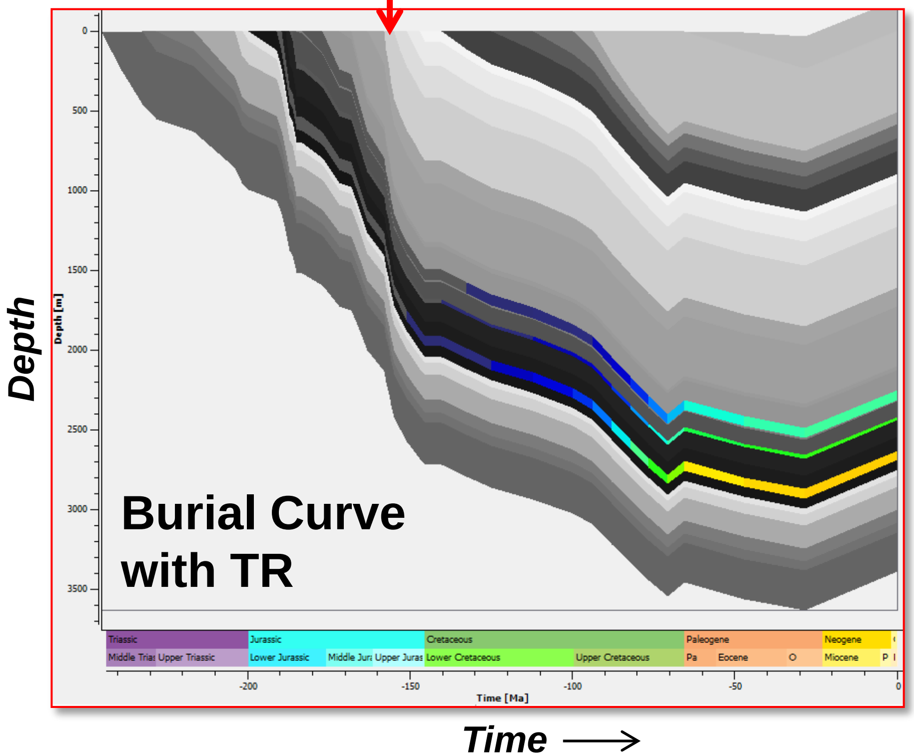


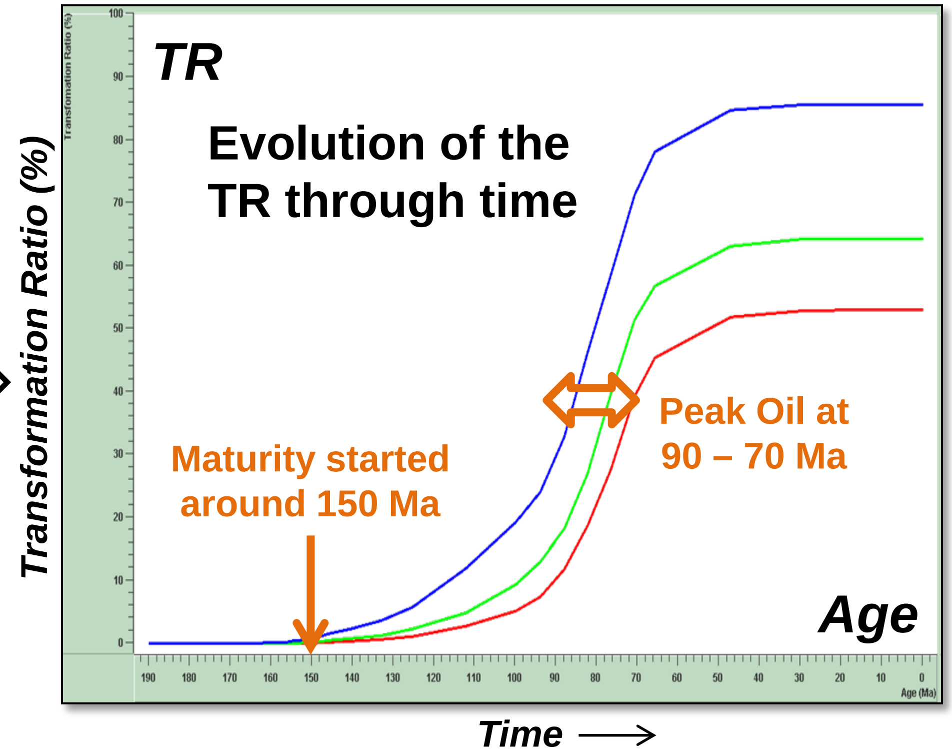
Maturity Timing
Section EW1

Modelling Results



Schistes Carton
Amaltheus
Sinemurian

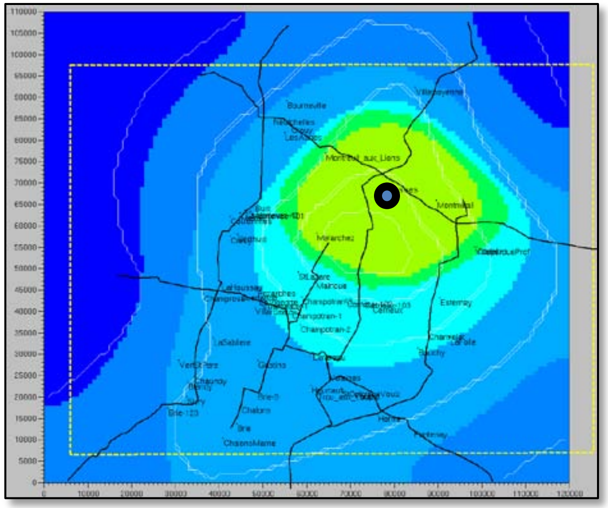




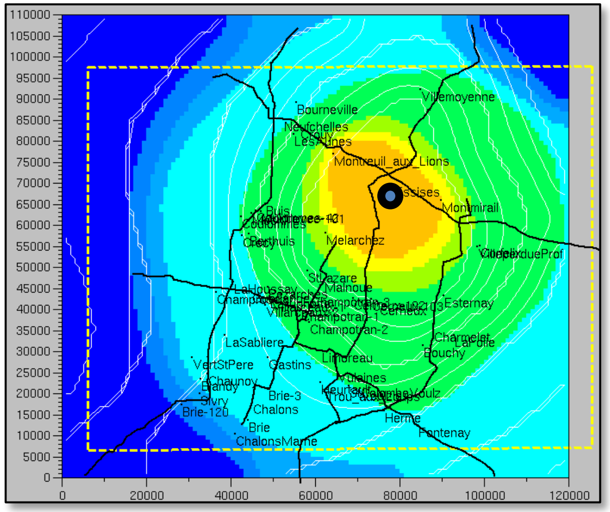
TR maps updated with 2D modeling results

Interpolation of Modeling Results

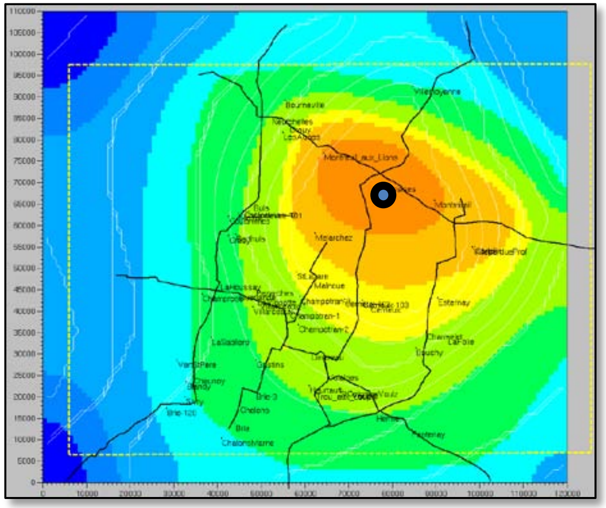
Schistes Carton SR

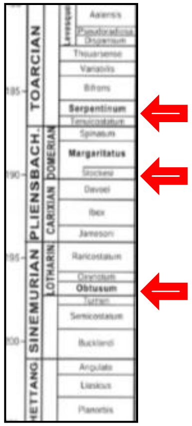


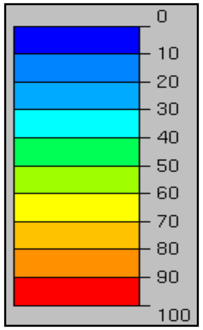
Amaltheus Shale SR



Sinemurian SR

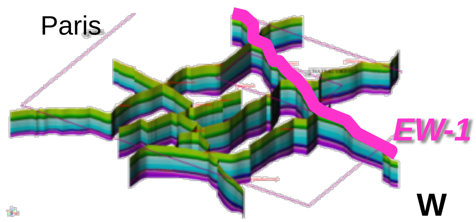


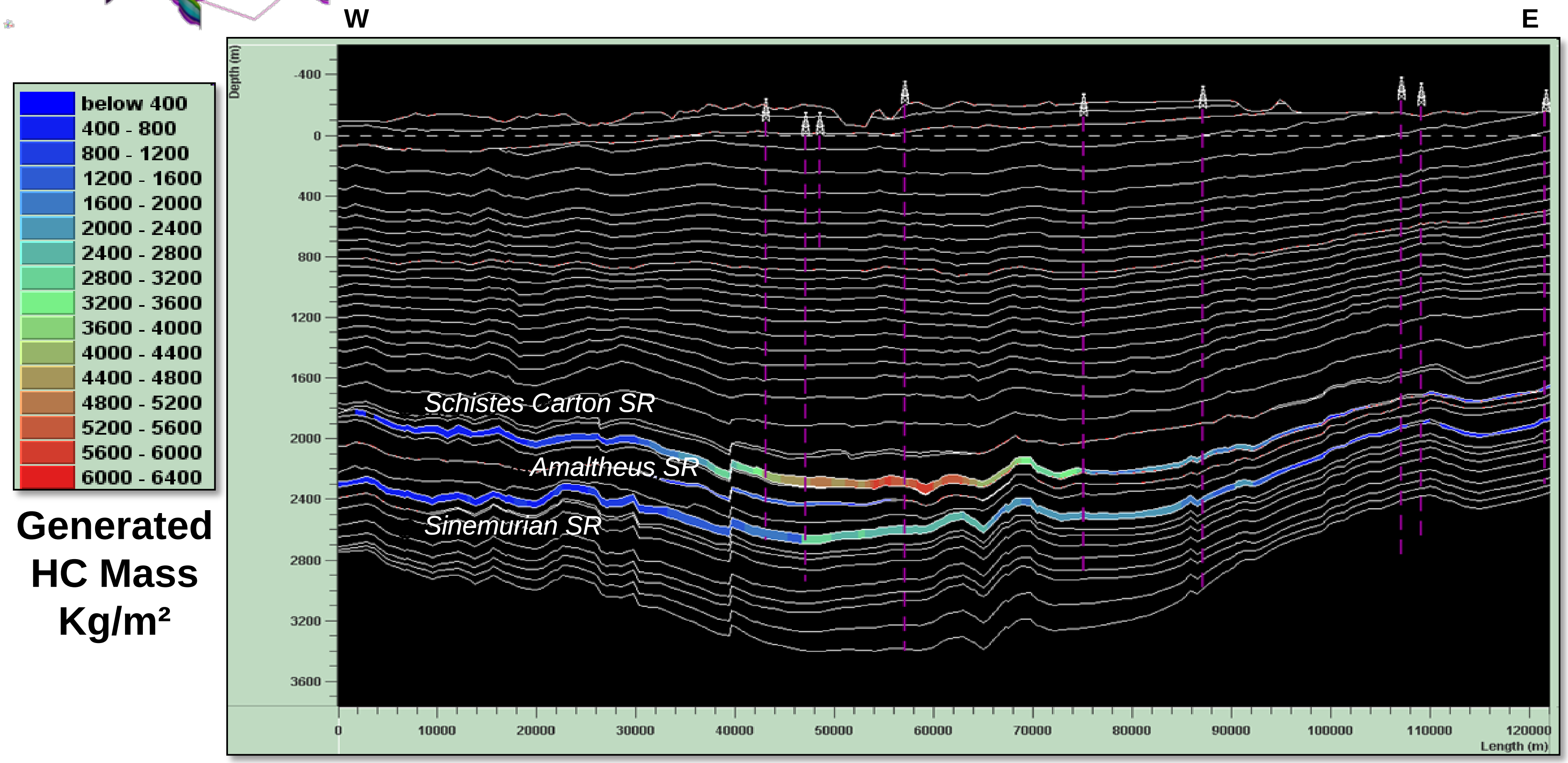




TR (%)

Generated HC Mass
Section EW-1





Generated HC Mass Kg/m²

Modeling Results

In Place HC
Section EW-1

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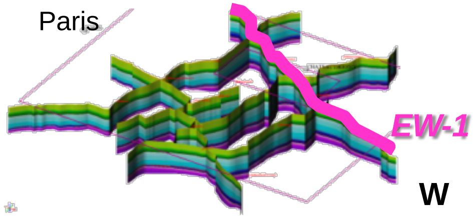

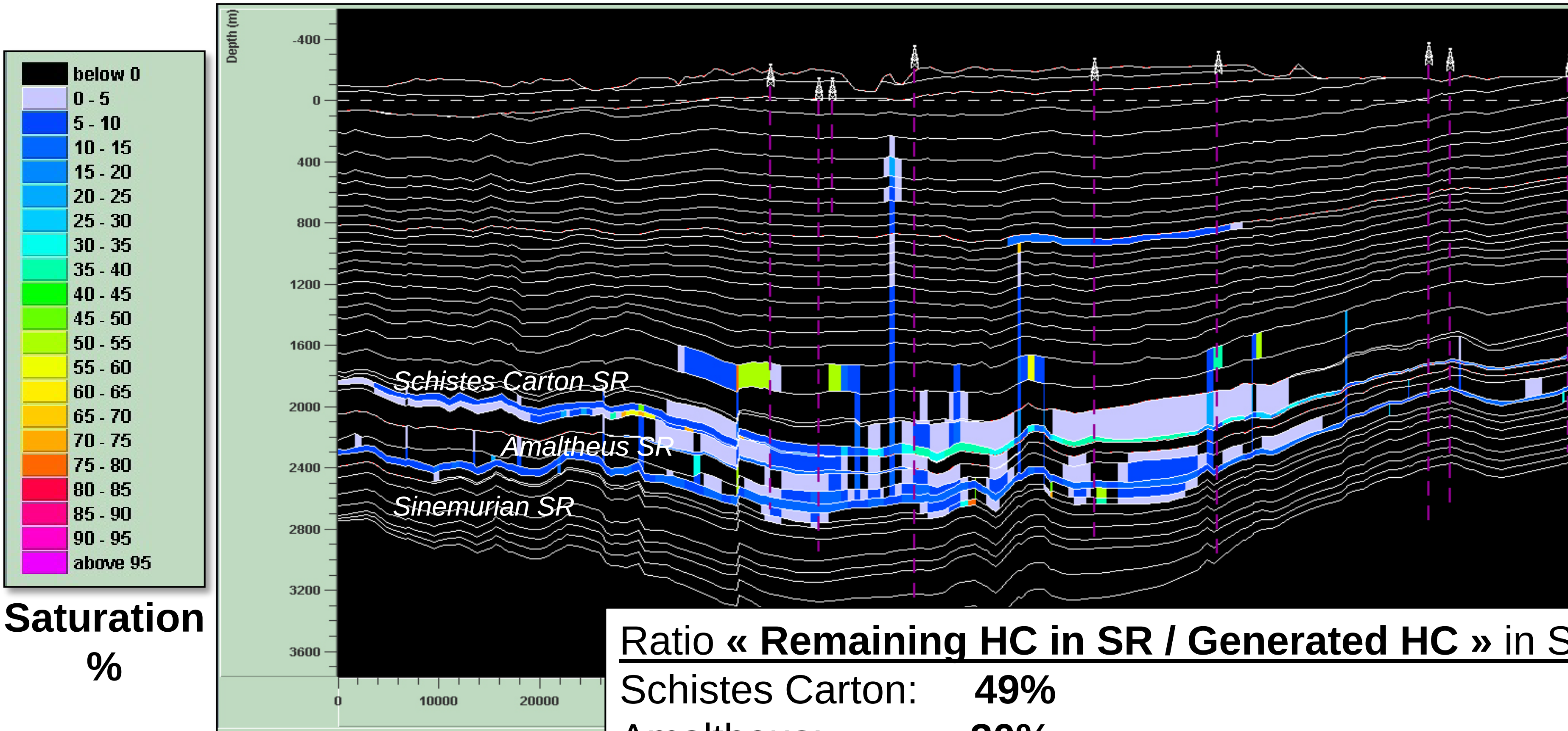

Saturation %

Modeling Results

Ratio « **Remaining HC in SR / Generated HC** » in SR:

Schistes Carton:	**49%**
Amaltheus:	**30%**
Sinemurian:	**37%**

Calculation of HC Volumes

Evaluation of remaining HC resources (at basin scale – 3D)
in SR layers with:

- Source Rock thickness maps
- TOC maps
- Transformation Ratio maps (from Temis 2D)
- Average ratio « remaining HC / generated HC » (from Temis 2D)

Calculation of HC Resouces Workflow (1/2)

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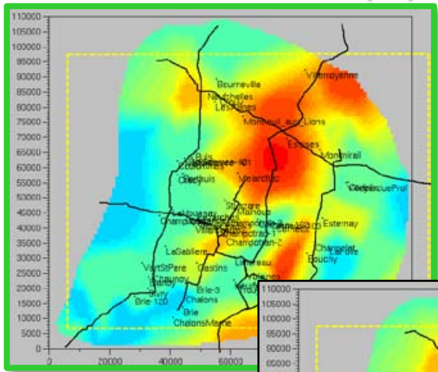
For each SR layer…

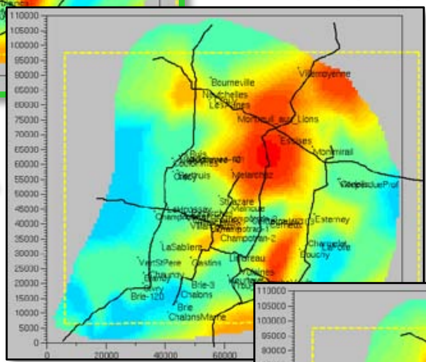
SR Bulk Thickness (m)



IFP Atlas, 2002

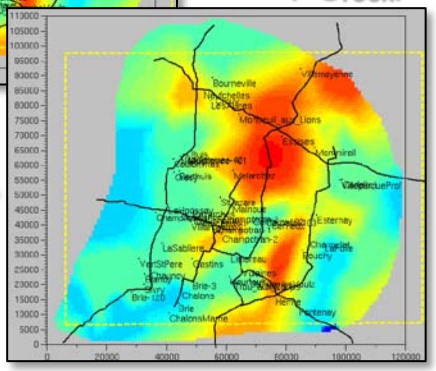
x 0.8 =
(20% average total micro porosity)

"Effective" Thickness (m)



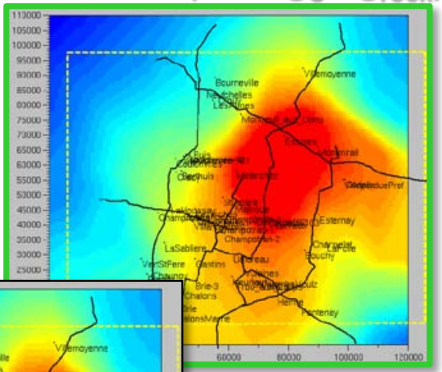
x 2645 kg/m³ =
(average mineral density)
x 1000000 m²
(cell surface)

Rock Mass (kg_{rock})



From well data and Temis 2D

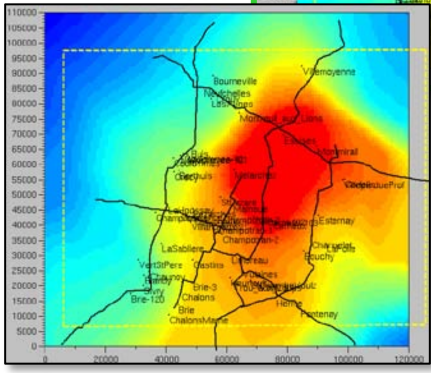
Initial TOC (% - kg_C/kg_{rock})



Modified from IFP Atlas, 1996

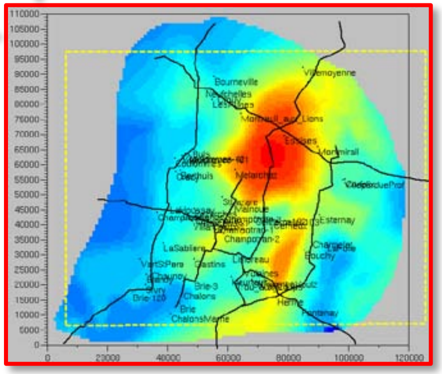
x 0.6 kg_{HC}/kg_C =
(HI = 600 mg_{HC}/g_C)

Maximum S2 (kg_{HC}/kg_{rock})



x

Maximum Potential HC Mass (kg_{HC})

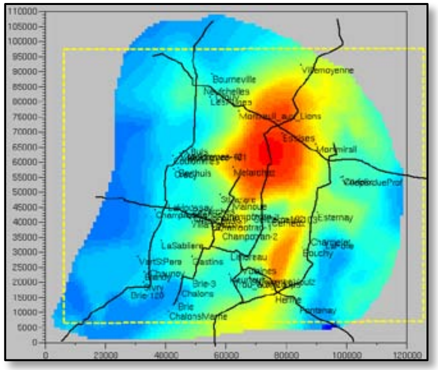


…

Calculation of HC Resouces Workflow (2/2)

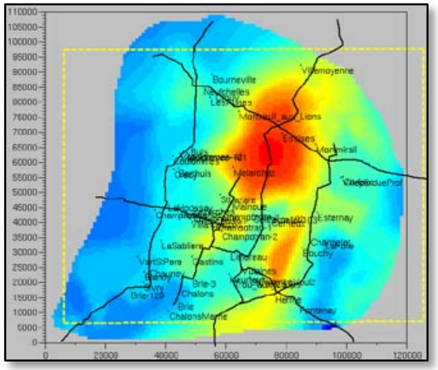
For each SR layer…

Maximum Potential HC Mass (kg)

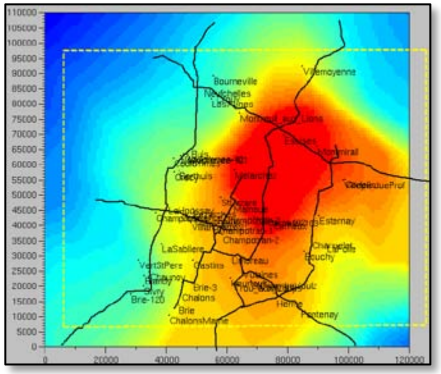


/ 840 kg/m³
(average oil density at surface condition)
/ 0.15897
(conversion in bbl)

Maximum Potential HC Volume (bbl)
(surf. cond.)

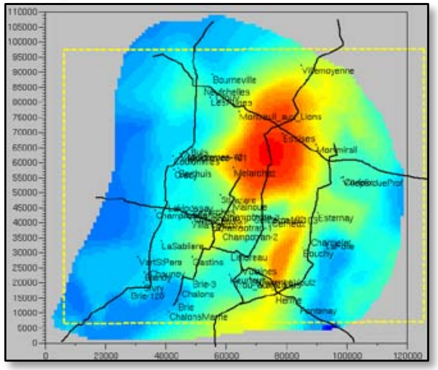


Transformation Ratio (%) ← *From Temis 2D*



x

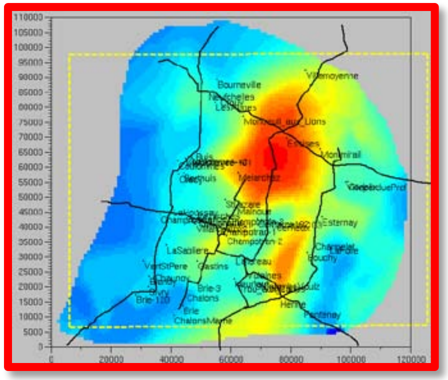
Generated HC Volume (bbl)
(surf. cond.)



From Temis 2D

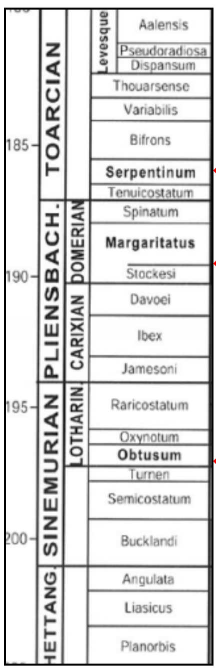
Average Ratio
« Remaining HC / Generated HC »

Residual HC Resource (bbl)
(surf. cond.)

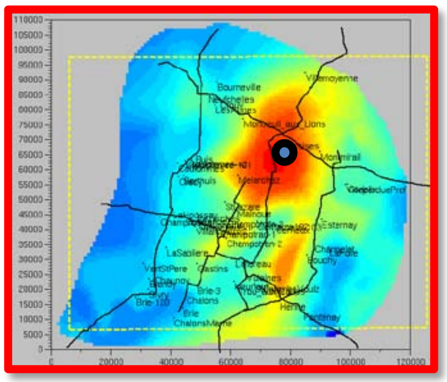


Non-Expelled HC Resources in Source Rocks of the Paris Basin

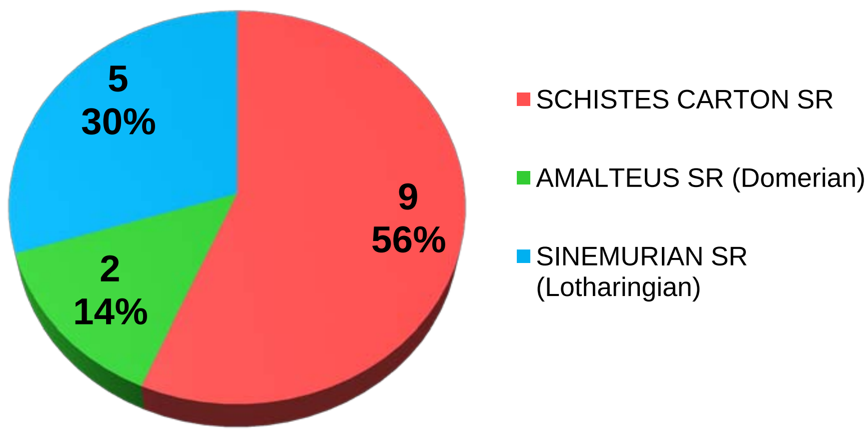
	Generated HC volume (calculated with TR) Bbbl	**Residual HC resource in SR layers Bbbl**	TR average
SCHISTES CARTON SR	45	**9**	32%
AMALTEUS SR (Domerian)	11	**2**	43%
SINEMURIAN SR (Lotharingian)	24	**5**	58%
TOTAL Bbbl	**81**	**16**	



*Volume calculated on **9 521 km²**.*



Residual HC resource in SR layers
Bbbl - % total



CONCLUSIONS

1. ***The dataset on the Paris Basin available in 2009 was abundant but old:***

   - *6 regional seismic lines (BRGM)*
   - *Source rock maps from geological atlases (IFP and BRGM)*
   - *Well data*

   → We integrated all for an evaluation at basin scale

2. ***A methodology based on TEMIS 2D models was developed for estimating HC volumes remaining in SR layers.***

3. ***The 3 Liassic source rocks GENERATED large volumes of HC in the Paris Basin, about 80 Bbbl in the study area (9 500 km²).***

   (0.25 Bbbl produced in conventional reservoirs)

4. ***REMAINING volumes in SRs = 16 Bbbl (>50% in the Schistes Carton).***

TEMIS basin modeling is a good tool to estimate HC volumes in Unconventional Plays.

A big thank you to Toreador Energy France for allowing the release of the study, and for the fruitful cooperation.

That's all folks