New Generation of Uncertainty Analysis in Basin Modeling*

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Search and Discovery Article #42508 (2020)**
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Abstract

Basin modelling englobes a range of geological disciplines which are used to describe the formation and evolution of sedimentary basins, often but not exclusively, to assess their potential for exploration and production of hydrocarbons. Understanding and being able to evaluate the uncertainties on a model are the key to deliver pertinent and in-depth analysis of the results as none of them can truly represent the reality. Current methods are based on advanced mathematical and statistical concepts that are applied on the dozens of physical parameters integrated in models to generate alternative scenarios. They stand up particularly effective when they are mastered but require a lot of experience in basin modelling as much as non-geological related field. Therefore, they remain used by a small community of experts instead of being widely adopted in E&P processes. Furthermore, the oil and gas industry face the dilemma that many of these experts will retire in the next few years without necessarily being able to pass the torch. This paper aims to present an innovative approach in basin modelling risk and uncertainty analysis. By using already developed advanced statistics optimization approaches and combining it with a new parametrization procedure based on well-known geological concepts instead of independent variables, this new workflow is designed to reach a wider and less experienced community while downsizing computing time and remaining agile and pertinent. The methodology identifies the key-elements of the petroleum system and guides the users in their estimations of the uncertainty based on the geological context in association with geological concepts coming from literature. Thus, it reduces the uncertainty evaluation to a few known concepts. In illustration of the general parametrization procedure, three new specific methodologies to assess the richness, the reactivity and the thickness of a source-rock are described following the philosophy of the workflow. They have been tested on a real case study over the Levantine Basin and present promising results as they required 50 times fewer simulations than Monte Carlo approach to provide results coherent with expected geological contexts and physical behaviors of the basin.

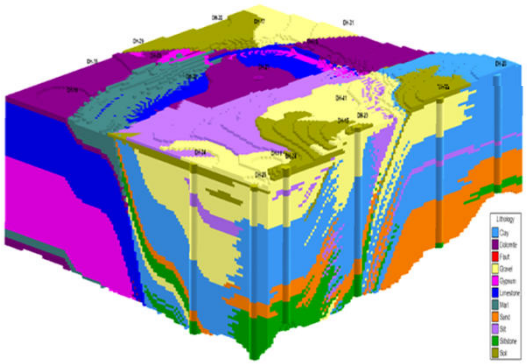
NEW GENERATION OF UNCERTAINTY ANALYSIS IN BASIN MODELING

PIERRE HACQUARD, MATTHIEU DUCROS, RENAUD TRABY, VÉRONIQUE GERVAIS, NICOLAS MAURAND*

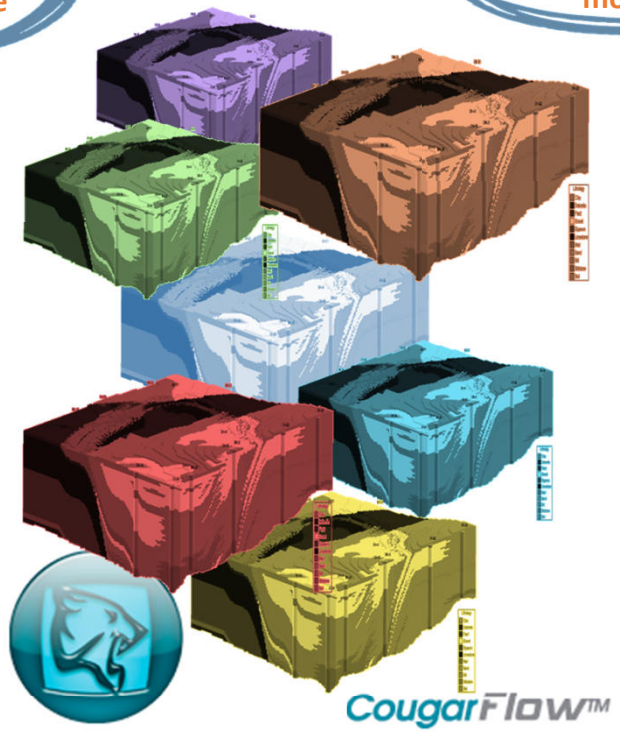
UNCERTAINTY ANALYSIS IN BASIN MODELING

Choose uncertain parameters in the model

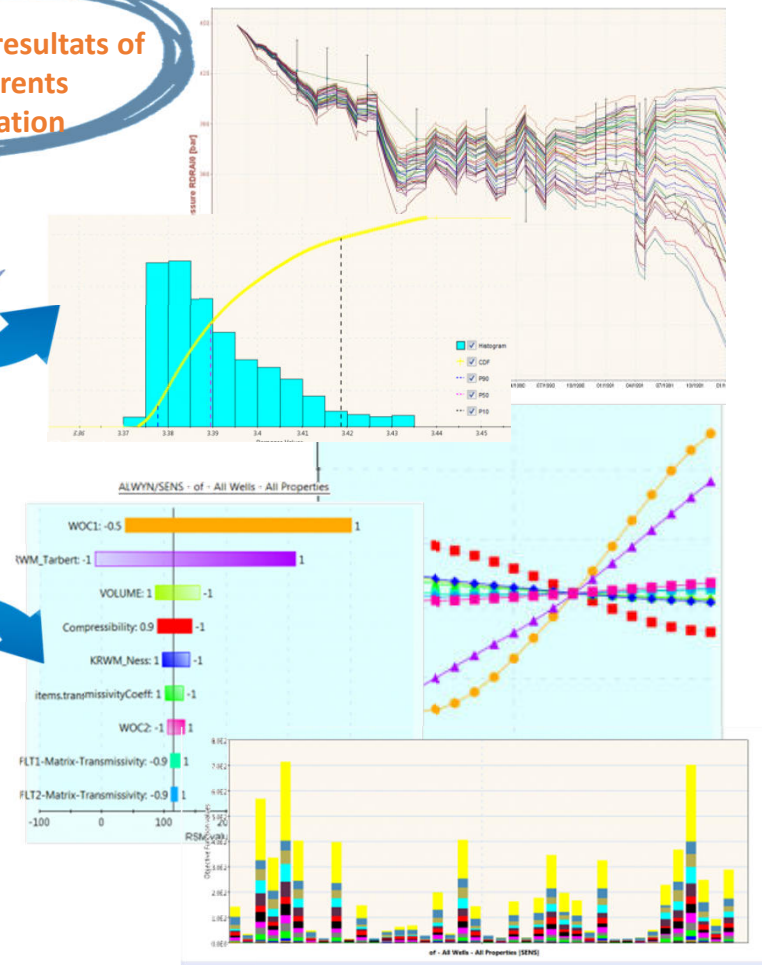
Compare the resultats of the differents modelization



Main Model



Multiple Modelization



X% variation on chosen parameters

WHY AN EVOLUTION IS NEEDED?

Uncertainty analysis is done by **Experts** only

Small Community

Not a reflex in E&P processes

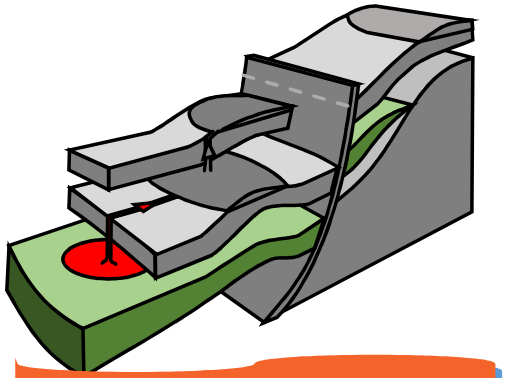
Evolution through a **Non-Expert based** experience

Bigger Community

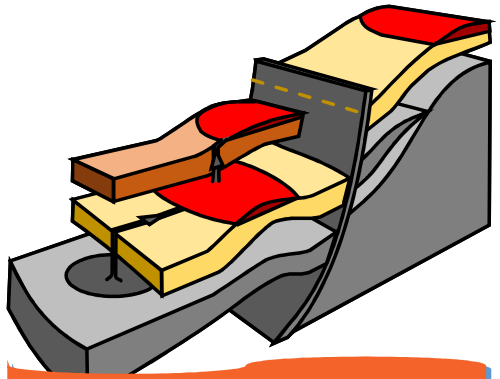
Systematic integration in E&P processes

NEW APPROACH

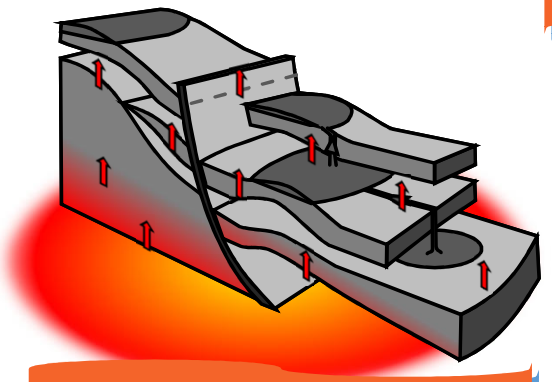
Gather parameters in **Group** representing **Geological Concepts**



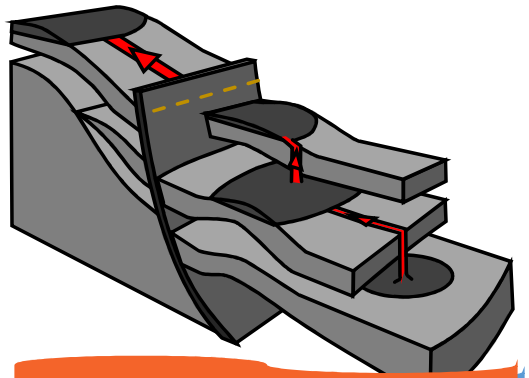
Source Rock



Reservoir



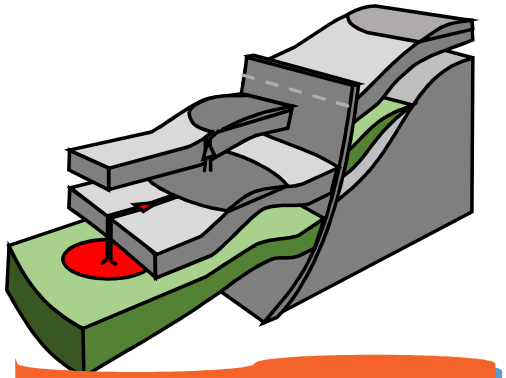
Maturity



Migration

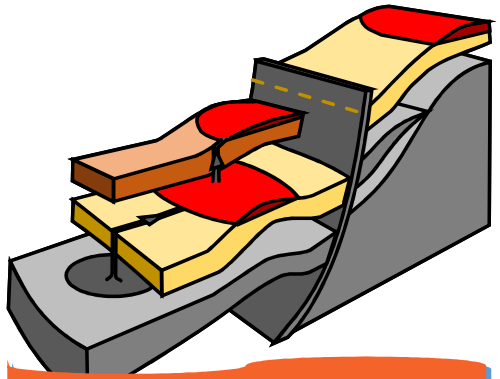
NEW APPROACH

Define meta-parameters **easily understandable** by the explorers



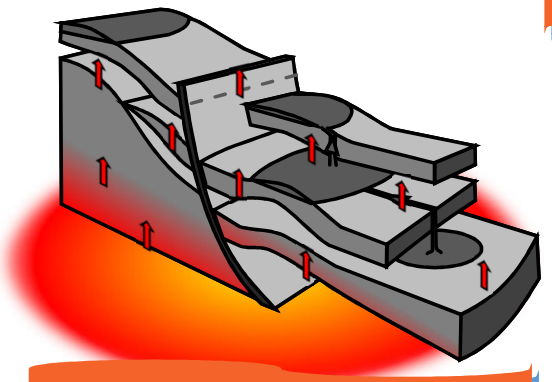
Source Rock

- Richness
- Reactivity
- Saturation
- Thickness



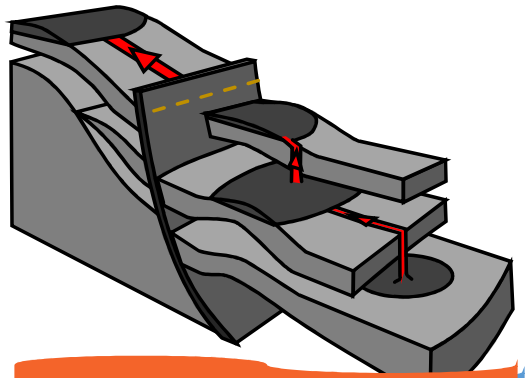
Reservoir

- Quality
- Seal
- Alteration



Maturity

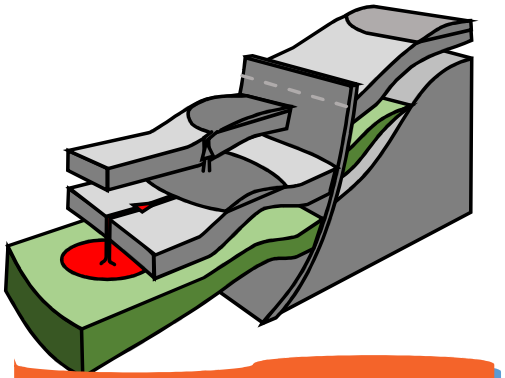
- Thermicity
- Crustal Model
- Thermal model



Migration

- Pathways
- Fluid Phases
- Mobility

NEW APPROACH



Source Rock

Define the uncertainties bounds in which **each parameter** evolve

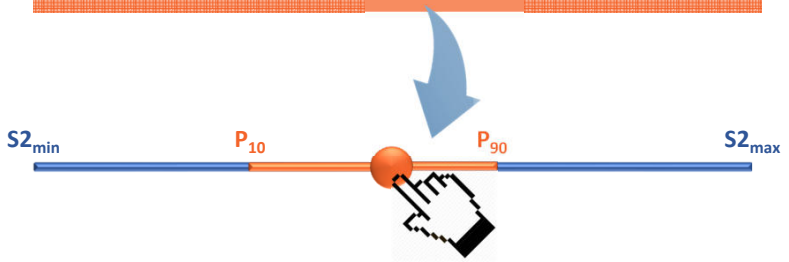
Richness

Reactivity

Saturation

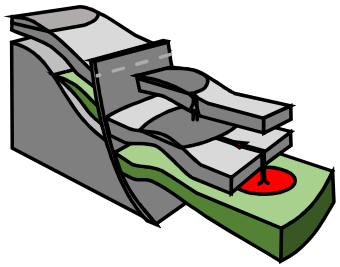
Thickness

The user modify the parameters **without worrying about process**



METHODOLOGY

For **each Meta-Parameter** we need to define :

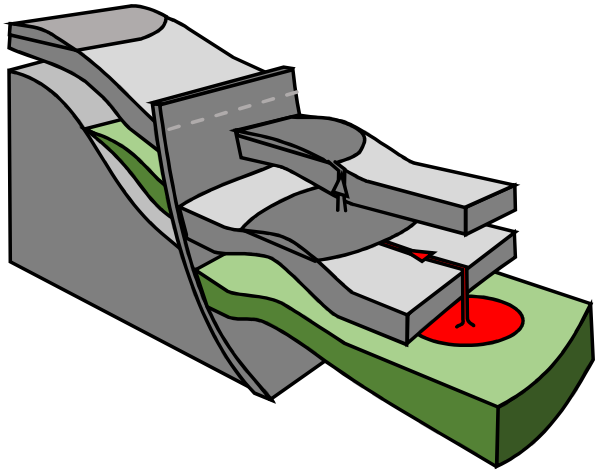


Source Rock

- Richness
- Reactivity
- Saturation
- Thickness

- **Parameters to include** : TOC, IH etc…
- **Relation between parameters** : TOC vs IH etc…
- **Methodology to evaluate the uncertainty on the Meta-Parameter**

≠ **DIFFERENT FOR EACH META-PARAMETER**



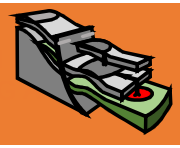
GROUP : SOURCE-ROCK

META-PARAMETERS DETERMINATION AND UNCERTAINTY ANALYSIS

Richness | Reactivity | Thickness

PARAMETERS SELECTION

SOURCE-ROCK
RICHNESS



Paramaters available in a Basin Model:

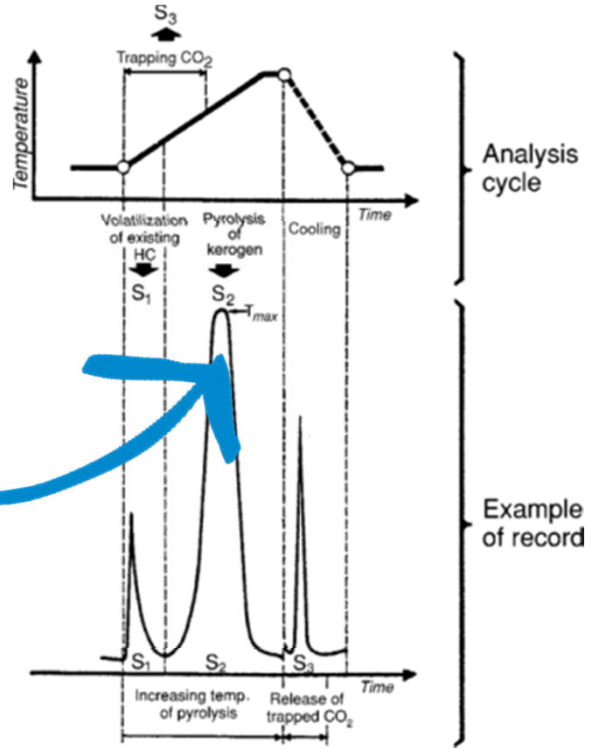
IH TOC

The **richness meta-parameter** must be a function of **IH** and **TOC**

$$S2 = IH \times TOC$$

with :

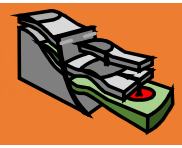
- **IH** : Hydrogen Index (mg HC/gC)
- **TOC** : Total Organic Content (mg C/ g rock)



Typical RockEval pyrolisis. Tissot, 1984

RELATION BETWEEN PARAMETERS

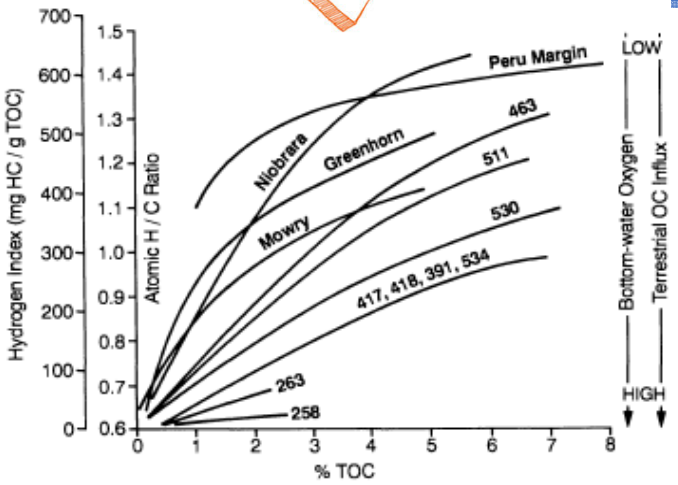
SOURCE-ROCK
RICHNESS



Is there a correlation between **IH** and **TOC**?

If yes, how to model it?

Bibliography : ✓



Tyson, 2001

IH and **TOC** are correlated

Modelization of **IH vs TOC** using **available data** in TemisFlow

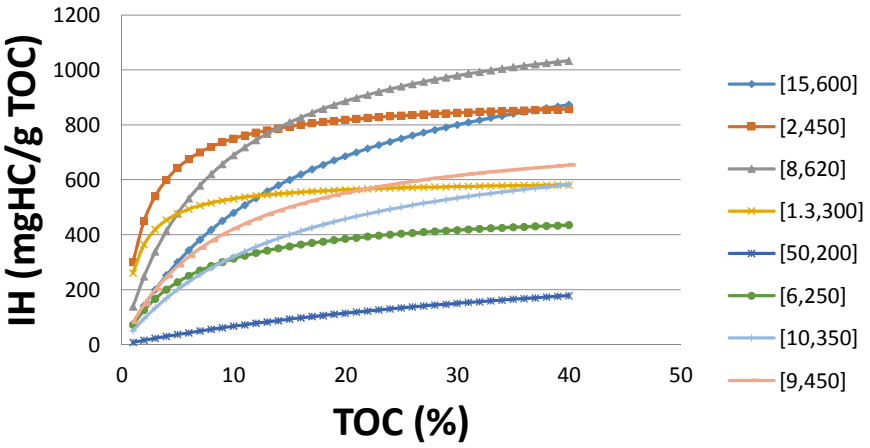
$$IH = a\frac{TOC}{1 + bTOC}$$

$$a = \frac{2 \times IH_{ini}}{TOC_{ini}}$$

$$b = \frac{1}{TOC_{ini}}$$

Model : ✓

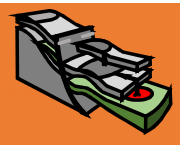
Modelization results for different [TOC,IH]



The model is **coherent**

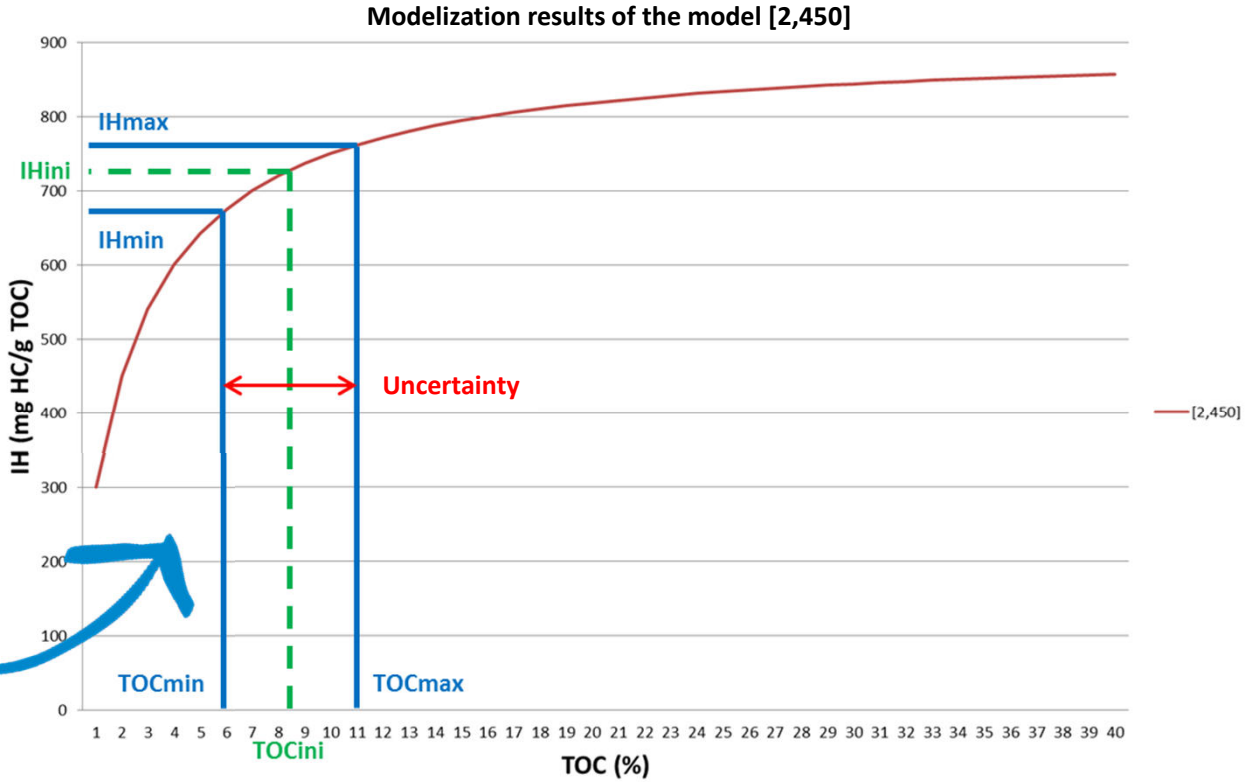
UNCERTAINTY EVALUATION METHODOLOGY

SOURCE-ROCK
RICHNESS



We now have a model correlating **IH** and **TOC**.

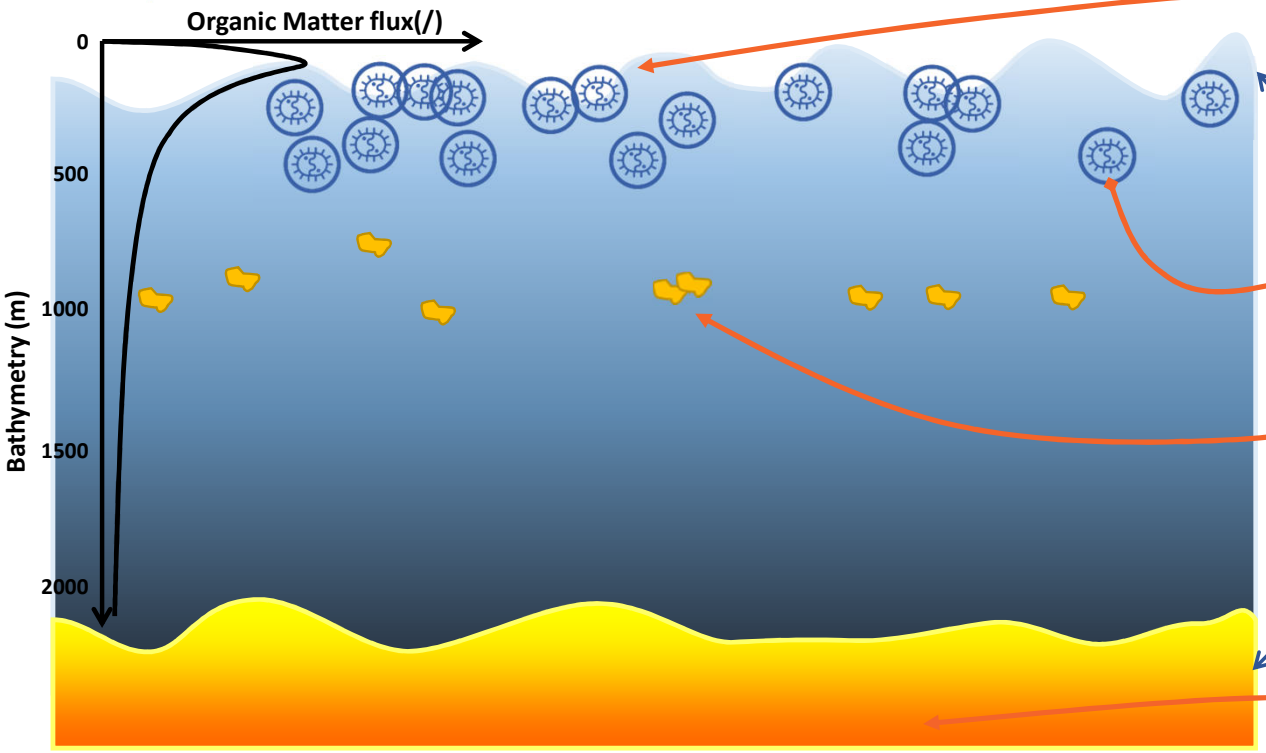
The uncertainty on the **TOC** **or** **IH** is enough to have the uncertainty on **Richness**.



In our approach, the uncertainty on **TOC** is going to be determined

What are the parameters **controling** the **TOC** ?

SOURCE-ROCK
RICHNESS



Primary Productivity: gC/cm²/a

Delivery Flux : gC/m²/a

Sedimentation Rate: cm/ka

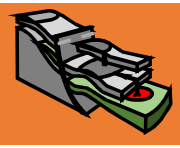
Bathymetry : m

Burial Efficiency: %

Hacquard, 2017

COMPUTING THEORETICAL TOC (TYPE II)

SOURCE-ROCK
RICHNESS



Delivery Flux (DF) :

$$DF = 9 \times \frac{PP}{H} + \frac{0,7 \times PP}{\sqrt{H}}$$

Bett & Holland, 1991

Burial Efficiency (BE) :

$$Log(BE) = \frac{1,39Log(S)}{Log(S + 7,9) + 0,34}$$

Bett & Holland, 1991

Theoretical TOC:

$$TOC = \frac{BE \times DF}{S \times 1000 \times \rho Roche}$$

Tyson, 2001

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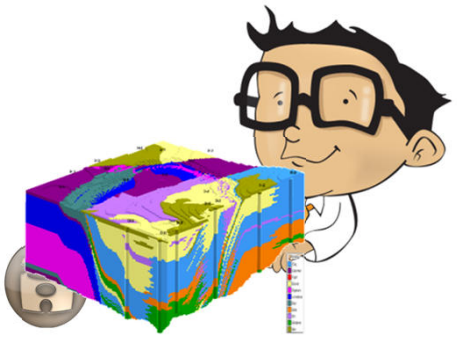
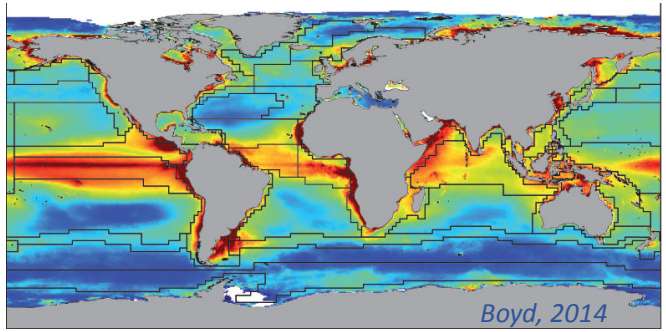
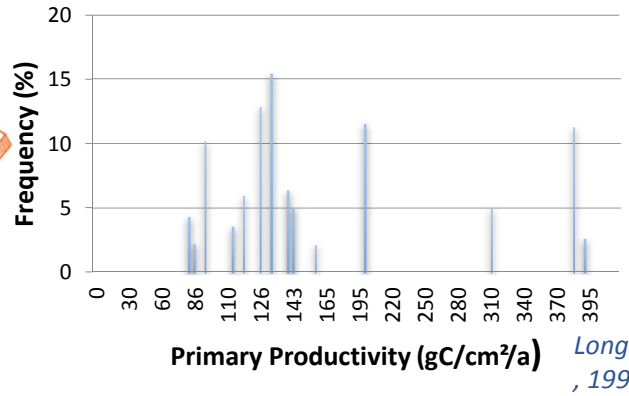


- Sedimentation Rate (S) ✓
- Density ($\rho Roche$) ✓
- Bathymetry (H) ✓
- Primary productivity (PP) ✗



Primary Productivity is not **Uniform** at the surface of the oceans

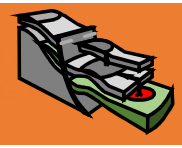


Longhurst , 1995

We can determine the **frequency** of the different PP values at the surface of the ocean

APPLICATION CASE : LEVANTINE BASIN

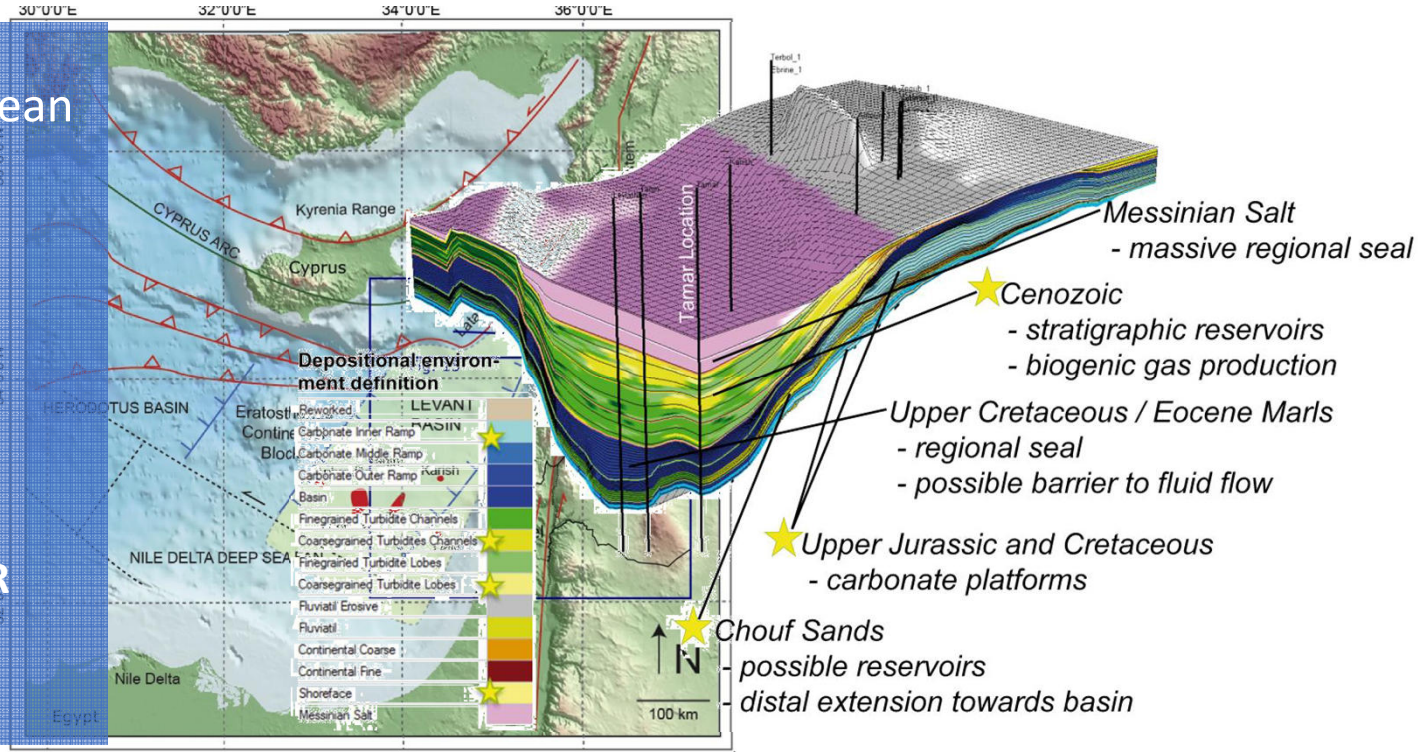
SOURCE-ROCK
RICHNESS



We need **to test** the methdology

- A **Frontier** basin in Mediterranean
- Recent **Giant** discoveries
- A **Lot** of uncertainties
- At least **5 source-rock**

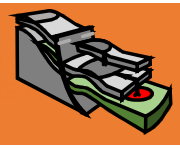
Analysis on the Cenomanian SR



Hawie, 2014

APPLICATION CASE : LEVANTINE BASIN - CENOMANIAN SR

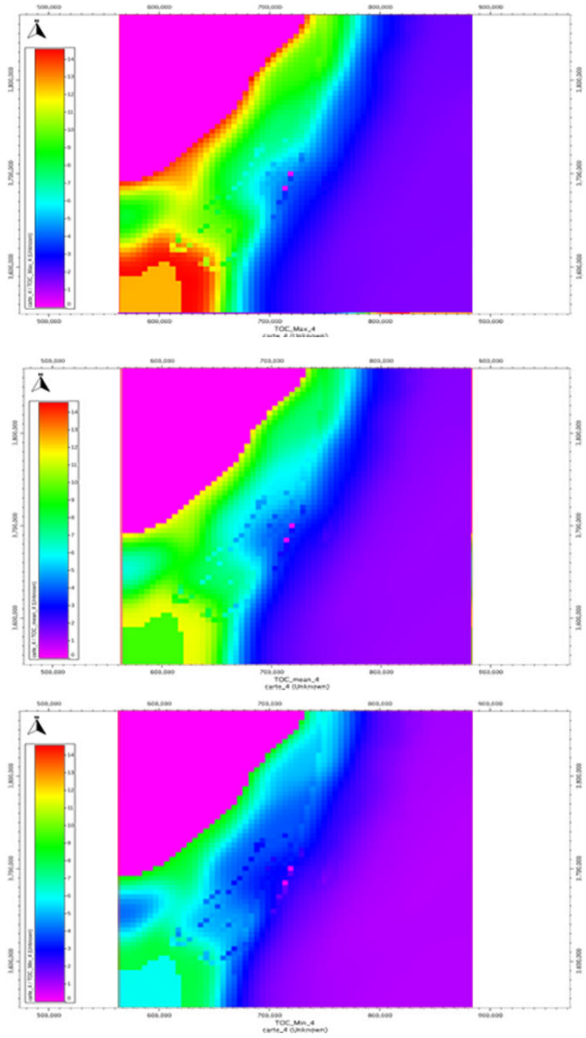
SOURCE-ROCK
RICHNESS



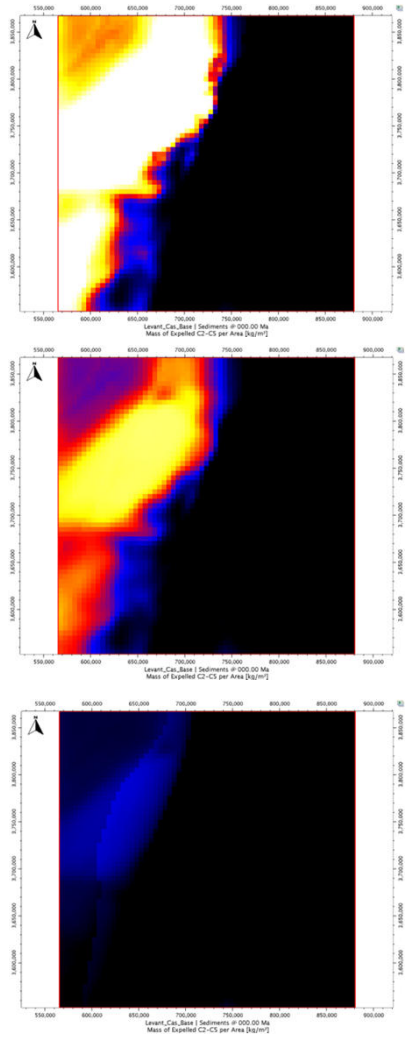
TOC_{max}

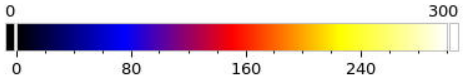
TOC_{User}

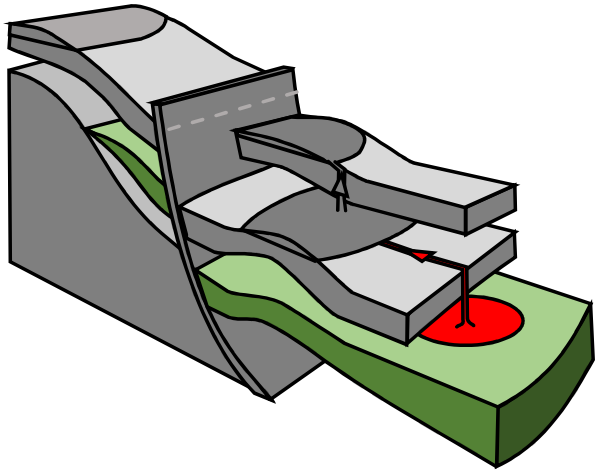
TOC_{min}



Expelled masses







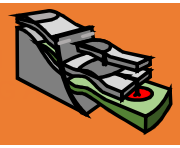
GROUP : SOURCE-ROCK

META-PARAMETERS DETERMINATION AND UNCERTAINTY ANALYSIS

Richness | Reactivity | Thickness

PARAMETER SELECTION

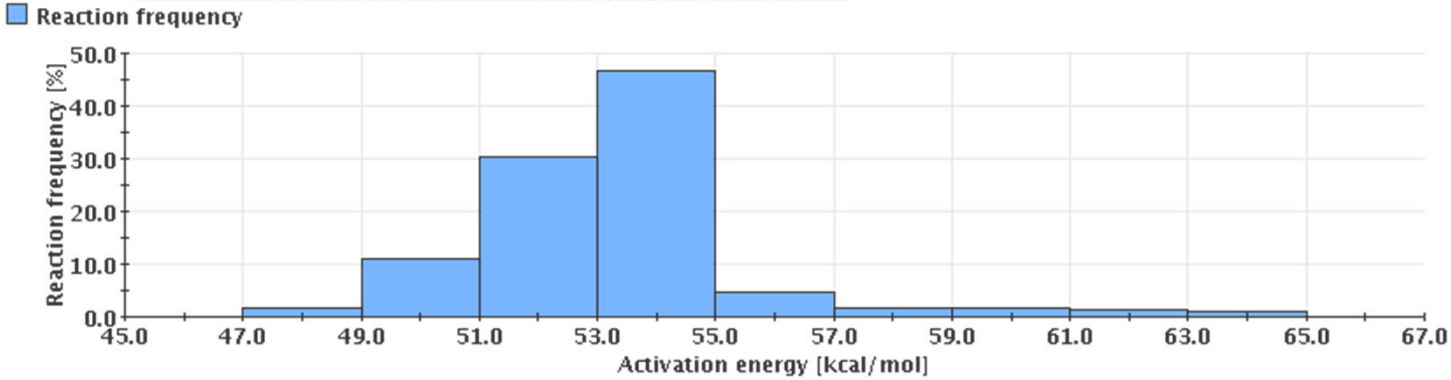
SOURCE-ROCK
REACTIVITY

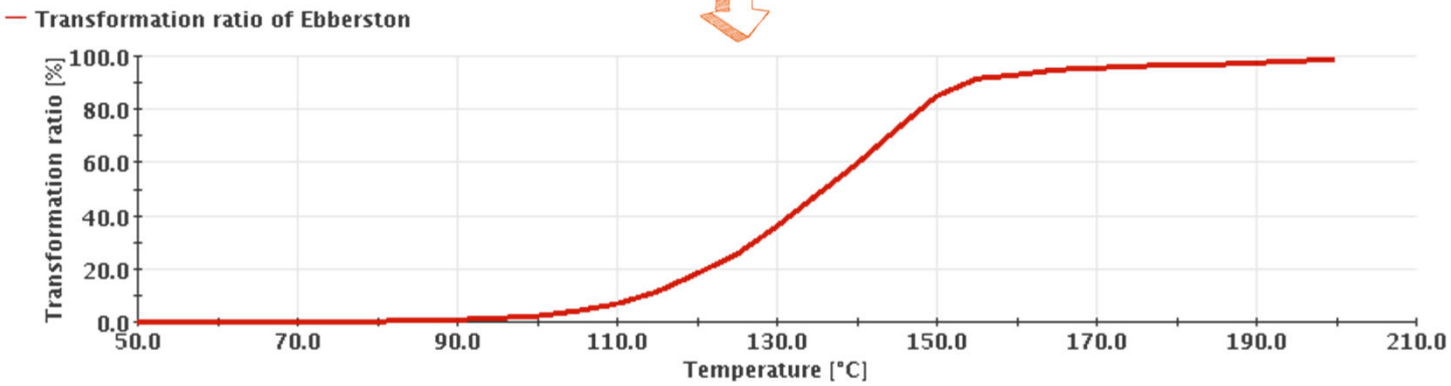


Arrhenius Law:

$$K = Ae^{\frac{-E}{RT(t)}}$$

- **A : Pre-Exponential factor**(s^{-1})
- **E : Activation Energy** (kJ/mol)





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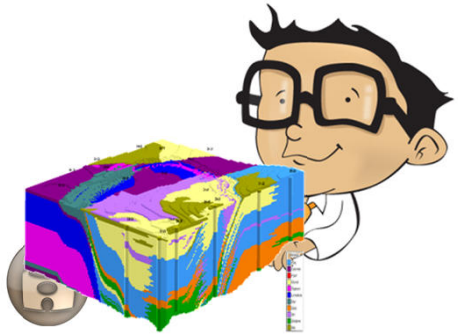
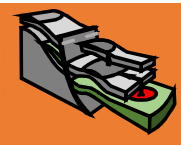


Activation Energies (E) ✓

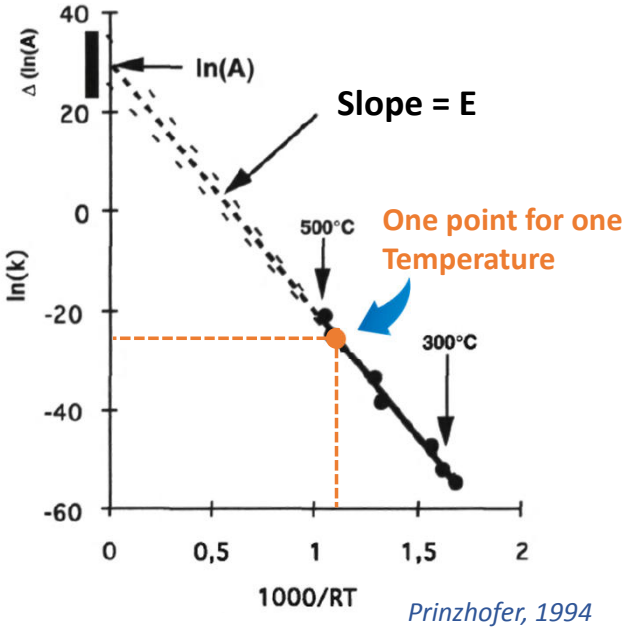
Pre-exponential Factor (A) ✓

UNCERTAINTY EVALUATION METHODOLOGY

SOURCE-ROCK
REACTIVITY

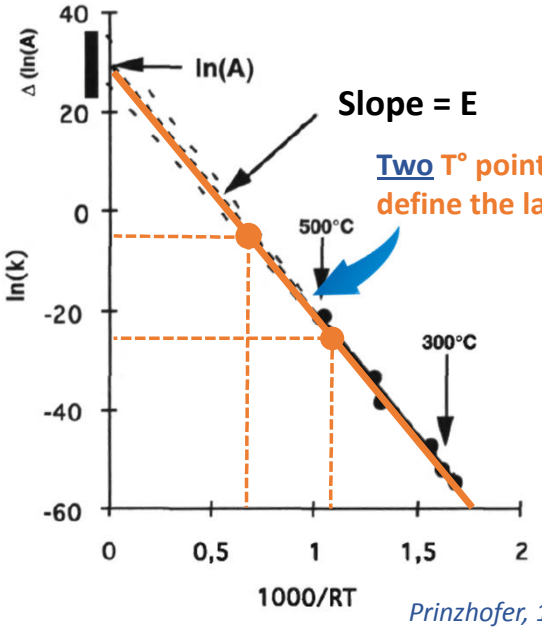


Laboratory Kinetic



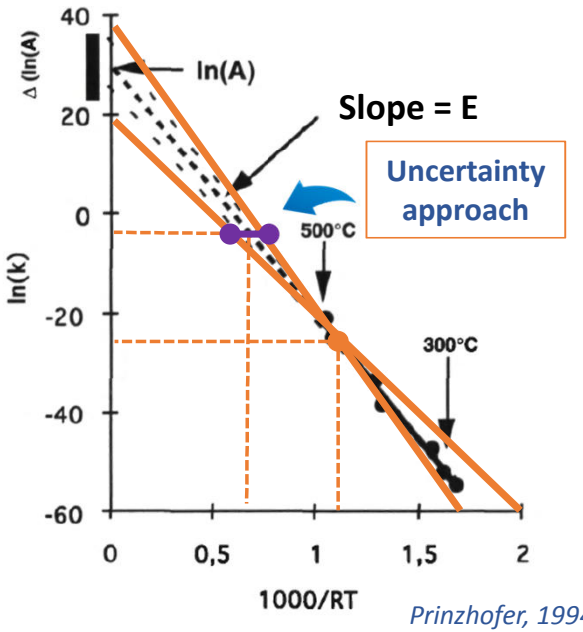
Prinzhofer, 1994

Unique A and Ea



Prinzhofer, 1994

Uncertainty on A and Ea

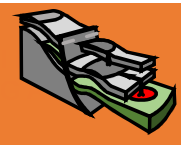


Prinzhofer, 1994

To apply this methodology **we need two temperatures** that can be applied on **all the Source-Rocks**, and an uncertainty for one of them

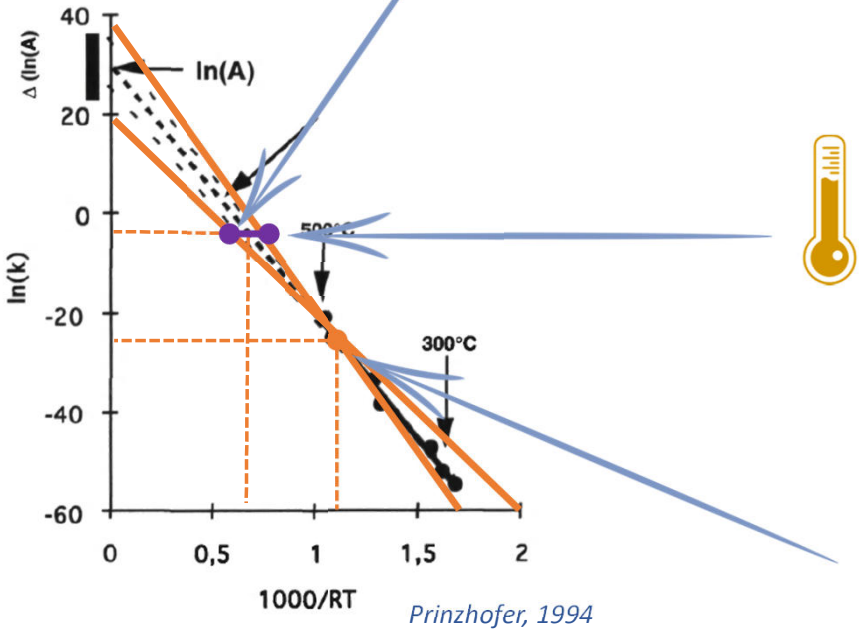
UNCERTAINTY EVALUATION METHODOLOGY

SOURCE-ROCK
REACTIVITY



$\sigma(x)$ **1-2°C**

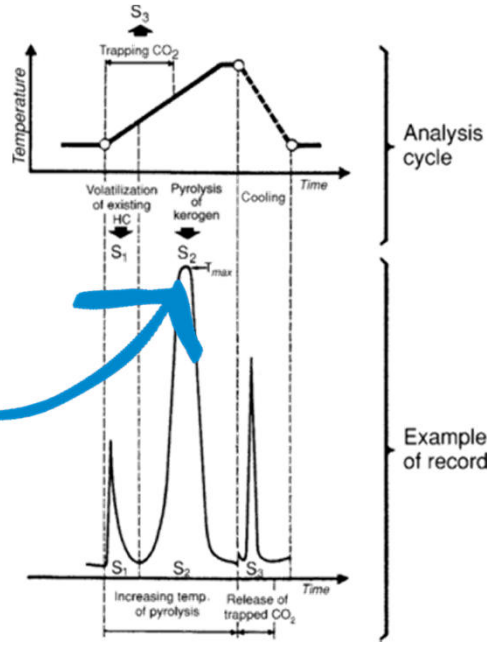
Maximum error recorded during laboratory manipulation in RockEval6



Prinzhofer, 1994

T_{max} (420°C - 460°C)

Unique for each Source Rock.



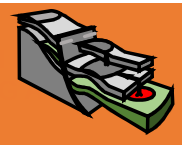
Typical RockEval pyrolisis. Tissot, 1984

375°C

Temperature **to reach the gas window** in a **RockEval 6** for an immature sample.

APPLICATION CASE : LEVANTINE BASIN - CENOMANIAN SR

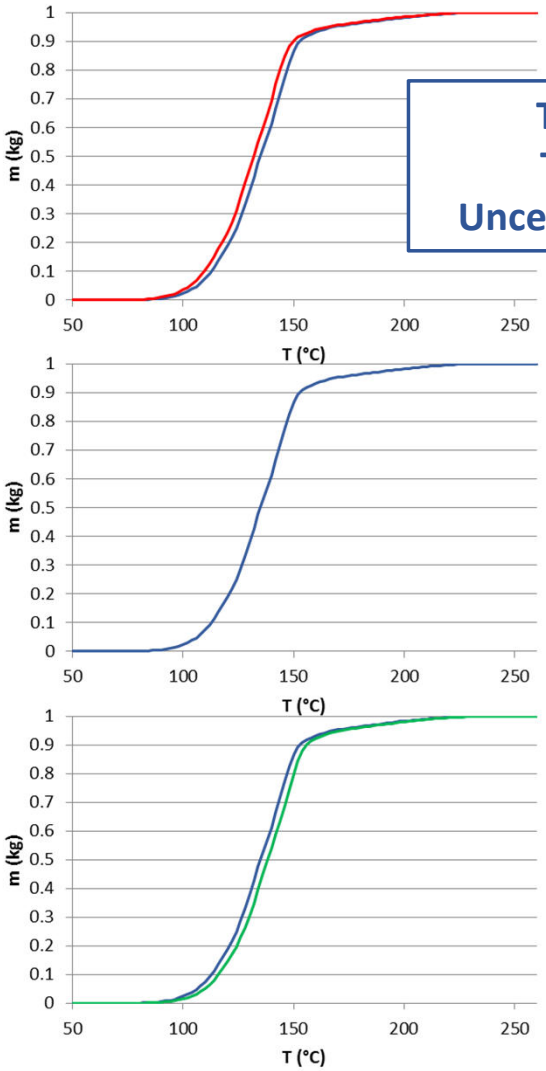
SOURCE-ROCK
REACTIVITY



$T_{max} + \sigma$

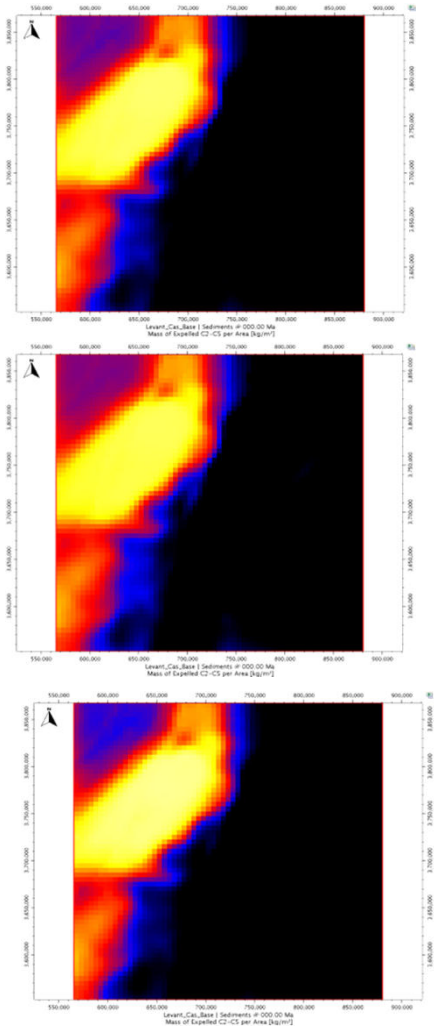
T_{max}

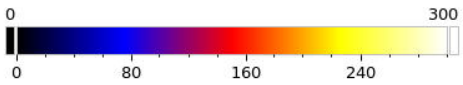
$T_{max} - \sigma$

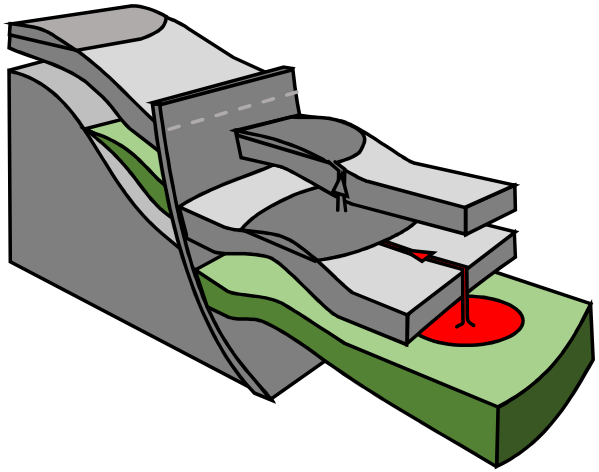


T_{max} = 420°C
T_{fixe} = 375°C
Uncertainty = +/- 1°C

Expelled masses







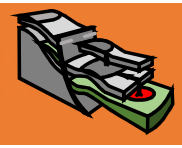
GROUP : SOURCE-ROCK

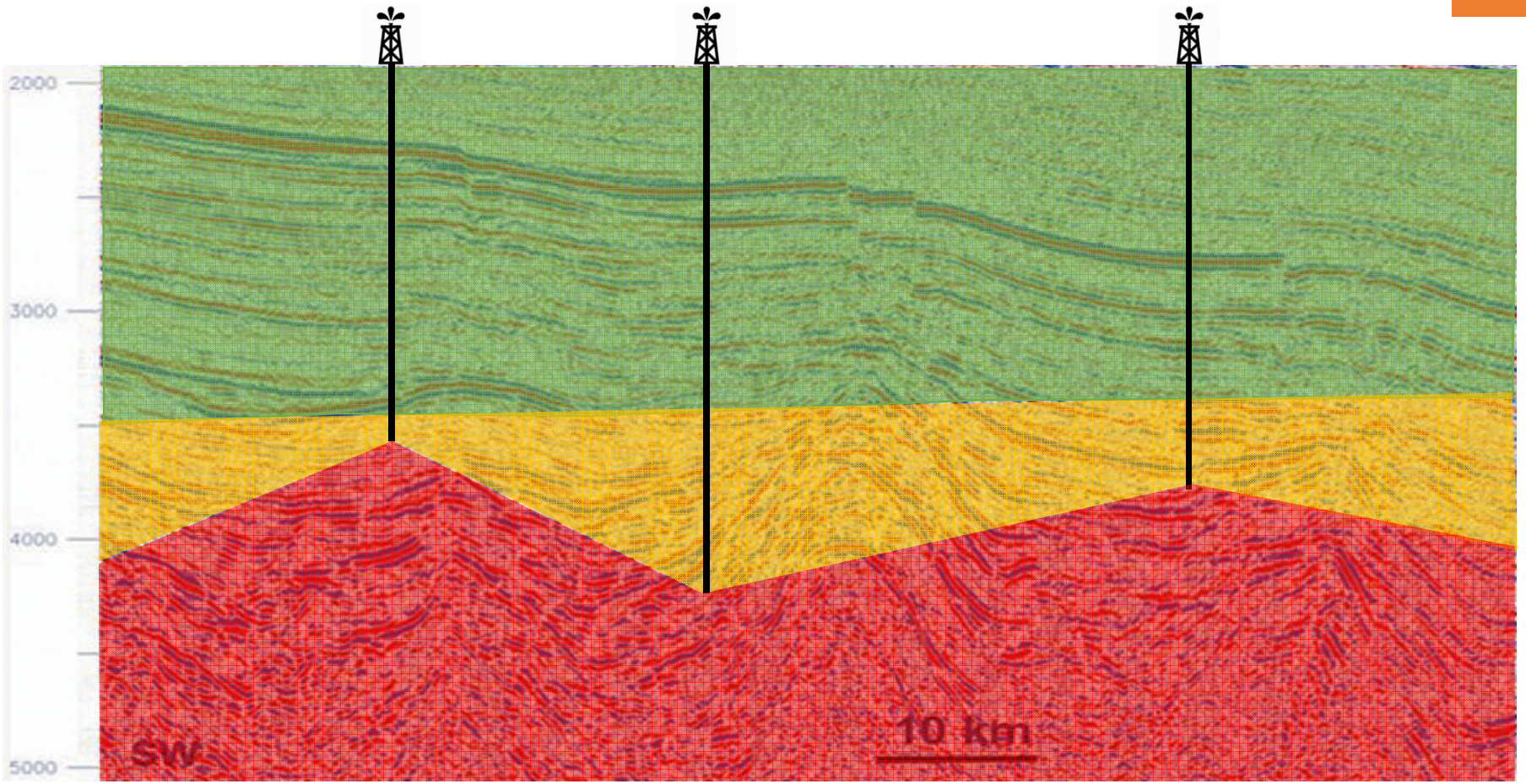
META-PARAMETERS DETERMINATION AND UNCERTAINTY ANALYSIS

Richness | Reactivity | Thickness

REALIABILITY OF THE THICKNESS

SOURCE-ROCK
THICKNESS





Good

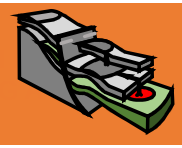
Global Reliability

Bad

How **important** can be the uncertainties in a 3D Model?

UNCERTAINTY EVALUATION METHODOLOGY

SOURCE-ROCK
THICKNESS



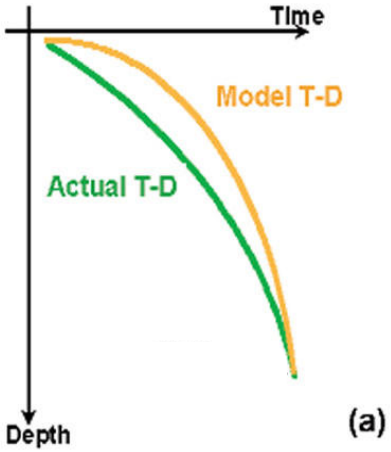
5-10 %

Maximum

Bibliography : ✓

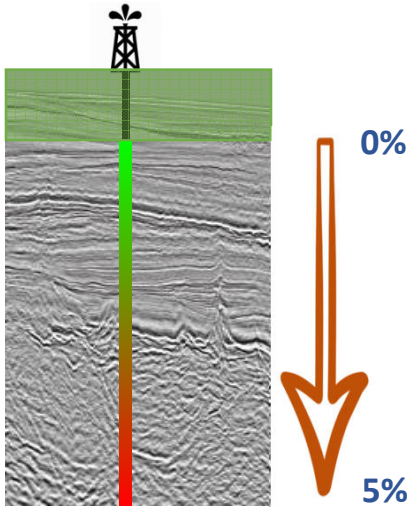
Landro 2001 , Niewland 2007

Error in Velocity Model



5 %

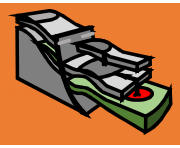
Distance from last Well



0 - 5 %

APPLICATION CASE : LEVANTINE BASIN - CENOMANIAN SR

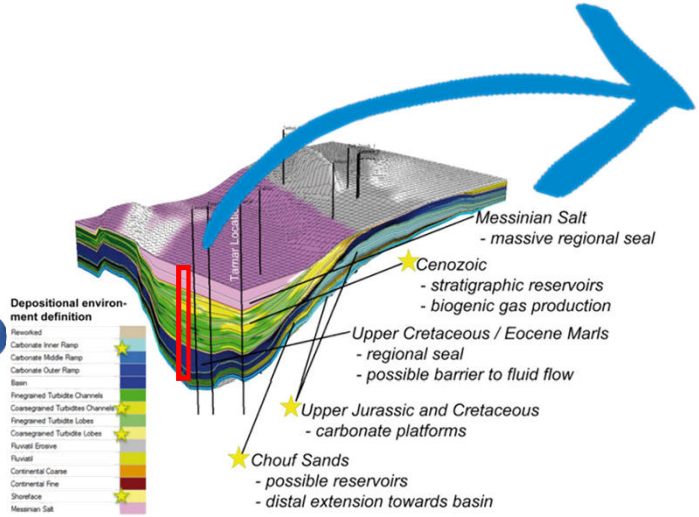
SOURCE-ROCK
THICKNESS



$Thickness_{max}$

$Thickness_{User}$

$Thickness_{min}$



MINIMUM
238
374
622
830
1005
1188
1207
1490
1645
1826
2043
2323
2436
2524
2639
2745
2949
3233
3315
3661
3852
4152
4365
4477
4580
4617
4987
5235
5329
5381
5709
6077
6287

MAXIMUM
263
414
688
918
1111
1314
1334
1646
1819
2018
2259
2567
2692
2790
2917
3033
3259
3573
3663
4047
4258
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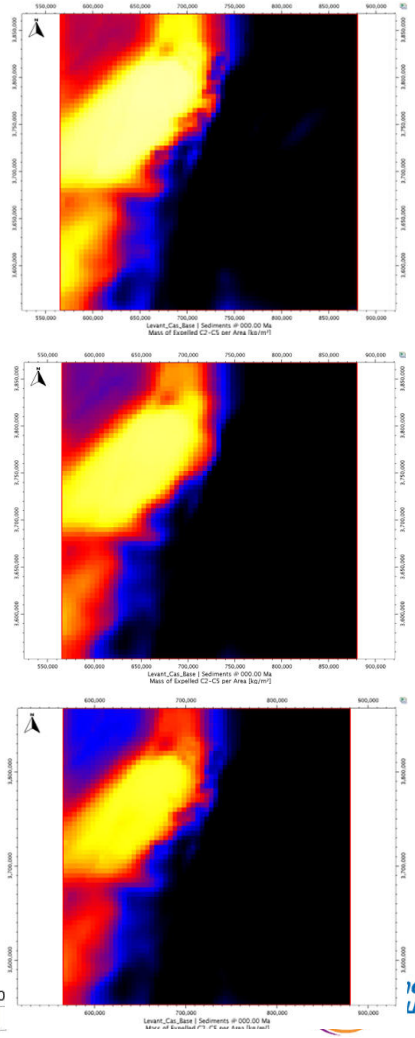
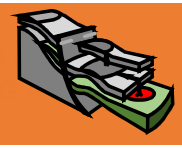
5103
5511
5787
5889
5947
6309
6717
6949

Expelled masses

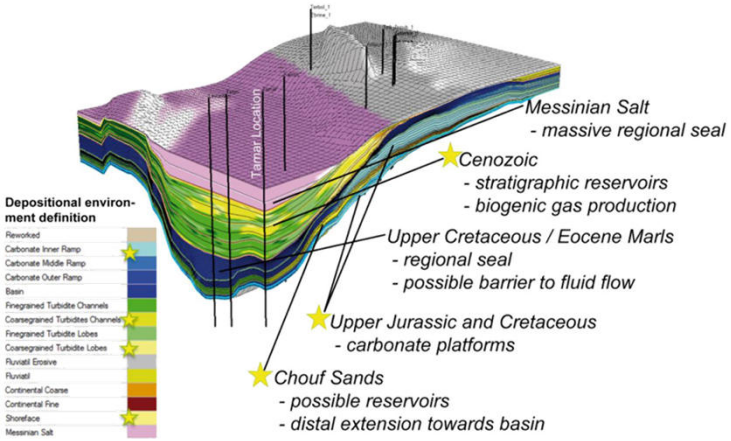


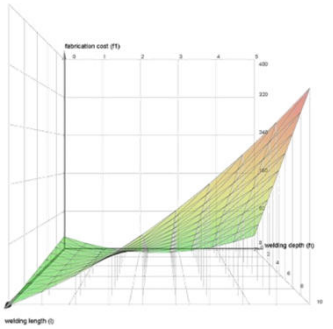
FURTHER WORK: LEVANTINE BASIN (COUGAR ANALYSIS)

SOURCE-ROCK
Further Work



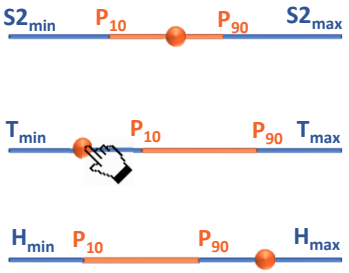
Richness + **Reactivity** + **Thickness**



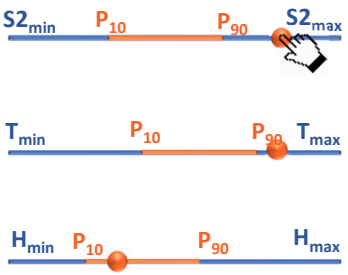


RESPONSE AREA

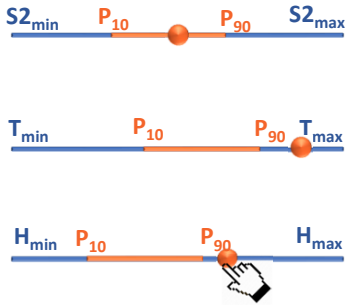
CAS 1



CAS 2

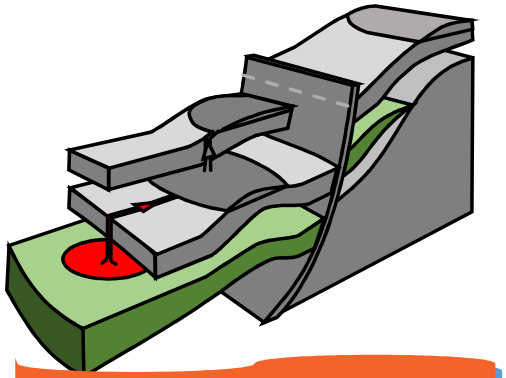


CAS 3



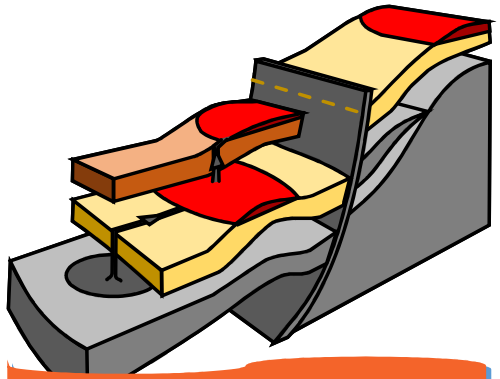
CAS X

FURTHER WORK



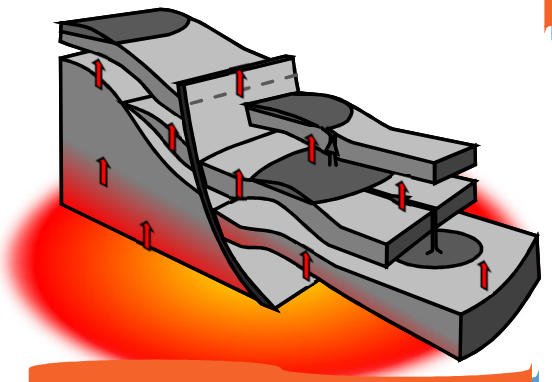
Source Rock

- Richness ✓
- Reactivity ✓
- Saturation
- Thickness ✓



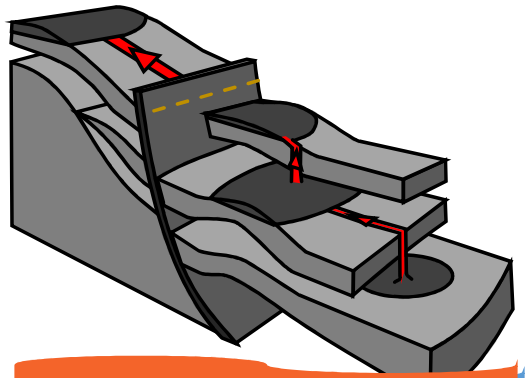
Reservoir

- Quality
- Seal
- Alteration



Maturity

- Thermicity
- Crustal Model
- Thermal model



Migration

- Pathways
- Fluid Phases
- Mobility

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