AAPG ACE 2018 - SALT LAKE CITY

20-23 May 2018 • Salt Lake City, Utah

AAPG ACE 2018

ANNUAL CONVENTION & EXHIBITION

The Importance of Evaluating **Initial Kerogen Potential** and **Restoring Kinetic Schemes** from **Mature Samples**

Example from Late Jurassic Source Rocks

*Matthieu **Dubille**, Gaelle **Maury**, Emerson **Marfisi**, Marie **Callies****

Beicip Franlab Headquarters
232, avenue Napoléon Bonaparte - BP 213
92502 Rueil Malmaison Cedex - France
Phone: + 33 1 47 08 80 00 - Fax: + 33 1 47 08 41 85
E-mail: info@beicip.com - www.beicip.com

BeicipFranlab

@Beicip-Franlab

Forewords

- **Is it really important to assess the initial source rock potential?**

  The difference between the initial potential and the remaining potential observed at present day gives the amount of hydrocarbons that may be found in the basin.

- **Is the workflow straightforward?**

  Not really… We will see the different cross checks to carry out between pyrolysis and kinetic data, and how to go « beyond the data ».

- **Should we account for all available data including first look imperfect or inconsistent geochemical dataset?**

  Yes! Every data has something to say…

Datasets

Presented data come from several studies, all source rocks are Upper Jurassic, deposited in carbonate-rich intra-shelf depressions.

@Beicip-Franlab

Pyrolysis Database **Observation**

- Things to know about pyrolysis processes:
  - Samples may have a long history from the well to the lab
  - There are different pyrolysis workflows and various devices
  - **There are several ways to prepare pyrolysis samples**

- Example of average pyrolysis results in a Upper Jurassic SR layer (46 measurements from a single well, each sample being analyzed twice: once “not prepared”, once “extracted”).

	Extracted	Not Prepared	Comment
TOC_t % (gC/gR)	1.7	2.1	TOC NOPREP higher (takes into account free HC)
$S1_t$ mgHC/gR	0.1	2	Small amount of free HC remains after extraction.
$S2_t$ mgHC/gR	**3.1**	***Mismatch!*** ⇔ **5.3**	S2t NOPREP higher (+171%) → abnormal overestimation of the remaining kerogen potential. The S2 should be the same in both samples
HI_t mgHC/gC	**165**	***Mismatch!*** ⇔ **251**	HI NOPREP higher (+152%) → abnormal overestimation of the remaining kerogen potential (the HI should be lower in Not Prepared samples because the TOC is higher)
$Tmax_t$ °C	**444**	***Mismatch!*** ⇔ **437**	Tmax NOPREP lower (-7°C) → abnormal underestimation of the maturity level

There is often a bias in the measurement of TOC, HI, S1, S2…

Remaining potential is often overestimated in Not Prepared samples → basin potential resources underestimated! Why?

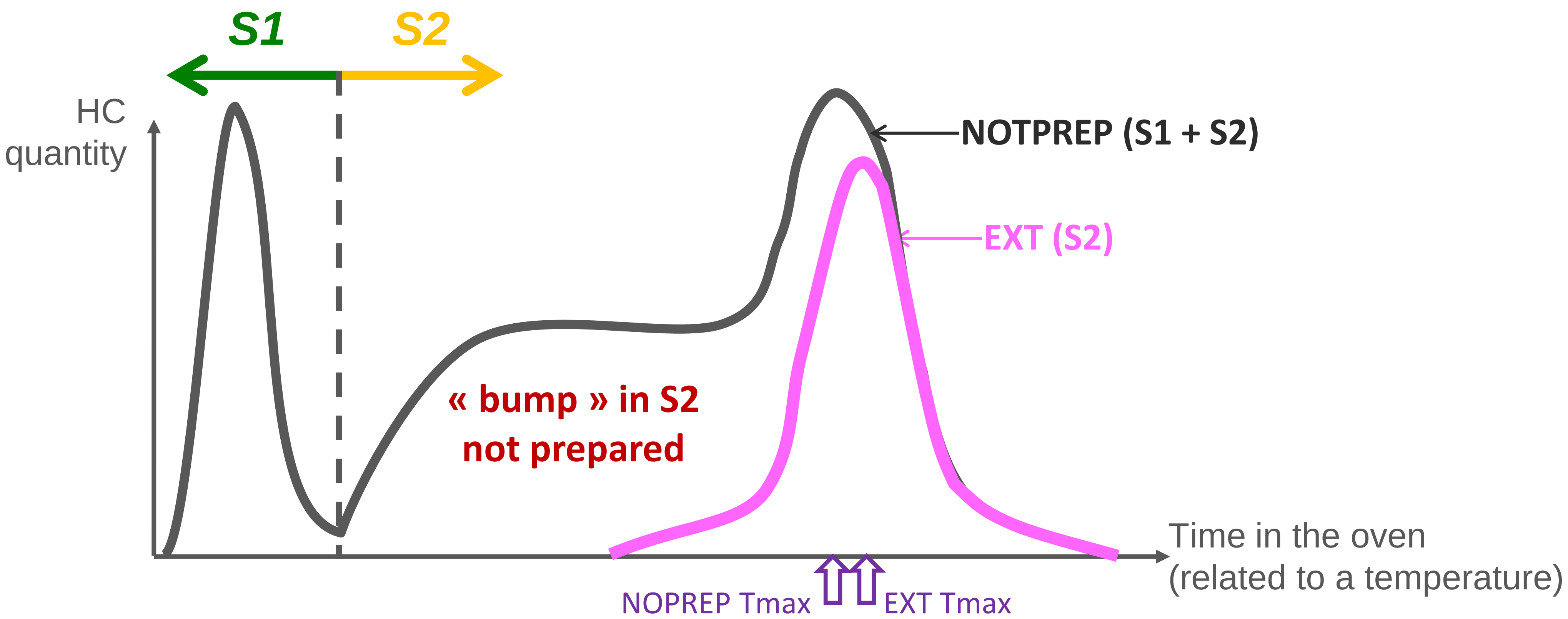
@Beicip-Franlab

Pyrolysis Database **Analysis**

- Example of 2 pyrograms, Not Prepared vs. Extracted samples

→ There is a « bump » before the main S2 peak of the Not Prepared sample.

→ Main S2 peaks are shifted



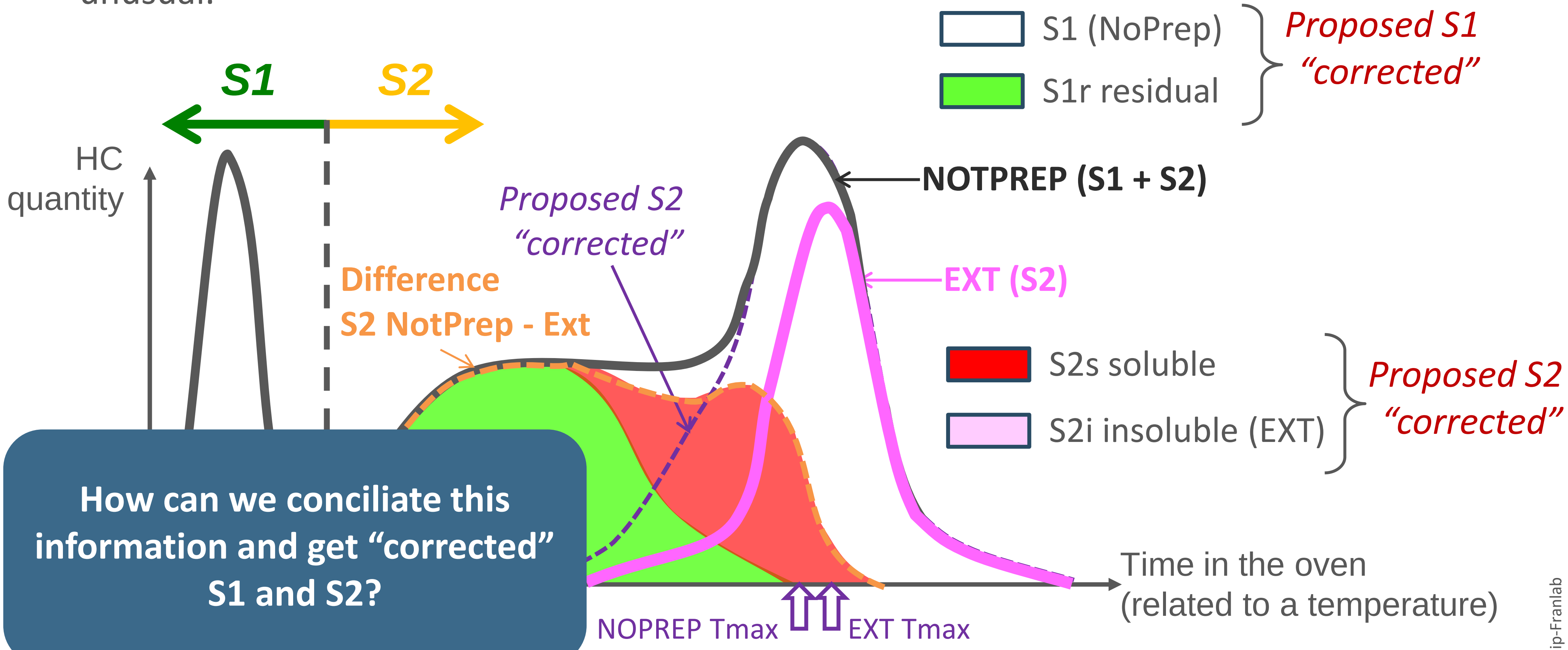
@Beicip-Franlab

Pyrolysis Database **Analysis**

Example of 2 pyrograms, Not Prepared vs. Extracted samples

→ This « bump » is observed in some kerogen, and SARA analysis indicates the massive presence of resins and asphaltens in source rock extracts.

→ The new IFPEN Rock-Eval **Shale Play® method** (Romero-Sarmiento et al., 2014; 2015) aims at improving the analysis of such kerogens, however such analyses are still unusual.



How can we conciliate this information and get "corrected" S1 and S2?

@Beicip-Franlab

Pyrolysis Database **Correction**

- TOC, HI, S2, S1 values are corrected in an Excel sheet (each sample), following a semi-automatic workflow based on mass balance. Tmax is not changed.

PYROLISIS DATA (input data)

comments	Top Depth	Sample PREPARATION	TOCt	HIt	S1t	S2t	S3t	Tmaxt	Vro
			gC/gR (%)	mgHC/gTOC	mgHC/gR	mgHC/gR			
Mean	**10423**		**1.9%**	**212**	**1.1**	**4.3**	**0.8**	**440**	**0.71%**
Mean if EXT			1.7%	165	0.1	3.1	0.8	444	
Mean if NOPREP			2.1%	251	2.0	5.3	0.9	437	
sample 1	10270	EXT	4.1%	220	0.1	9.1	0.9	443	
sample 1	10270	NOPREP	5.2%	187	3.9	9.6	1.4	443	
sample 2	10280	EXT	5.5%	208	0.2	11.4	0.9	446	
sample 2	10280	NOPREP	6.2%	280	4.9	17.4	0.9	442	
sample 3	10290	EXT	1.8%	182	0.1	3.4	0.8	443	
sample 3	10290	NOPREP	2.2%	232	1.4	5.0	0.8	438	
sample 4	10300	EXT	1.2%	176	0.1	2.1	0.7	444	0.69%
sample 4	10300	NOPREP	1.3%	263	0.9	3.5	0.7	436	

RESULTS / corrected & recalculated DATA

	TOC EXTRACTED EQUIV.	HI EXTRACTED EQUIV.	S2 EXTRACTED EQUIV.	S1 total
	gC/gR (%)	mgHC/gTOC	mgHC/gR	mgHC/gR
Mean	1.6%	193	3.1	2.3
Mean if EXT	1.6%	176	3.1	0.1
Mean if NOPREP	1.6%	208	3.1	4.1
sample 1 EXT	3.8%	239	9.1	0.1
sample 1 NOPREP	4.1%	137	5.7	7.9
sample 2 EXT	5.1%	224	11.4	0.2
sample 2 NOPREP	4.6%	224	10.3	12.1
sample 3 EXT	1.7%	195	3.4	0.1
sample 3 NOPREP	1.7%	175	2.9	3.5
sample 4 EXT	1.1%	188	2.1	0.1
sample 4 NOPREP	1.0%	204	2.1	2.3

Initially most of the dataset was rejected, especially NOT PREPARED samples.

After the homogenization the whole dataset can be used

Initial pyrolysis data (EXT and NOPREP samples)

Corrected pyrolysis data

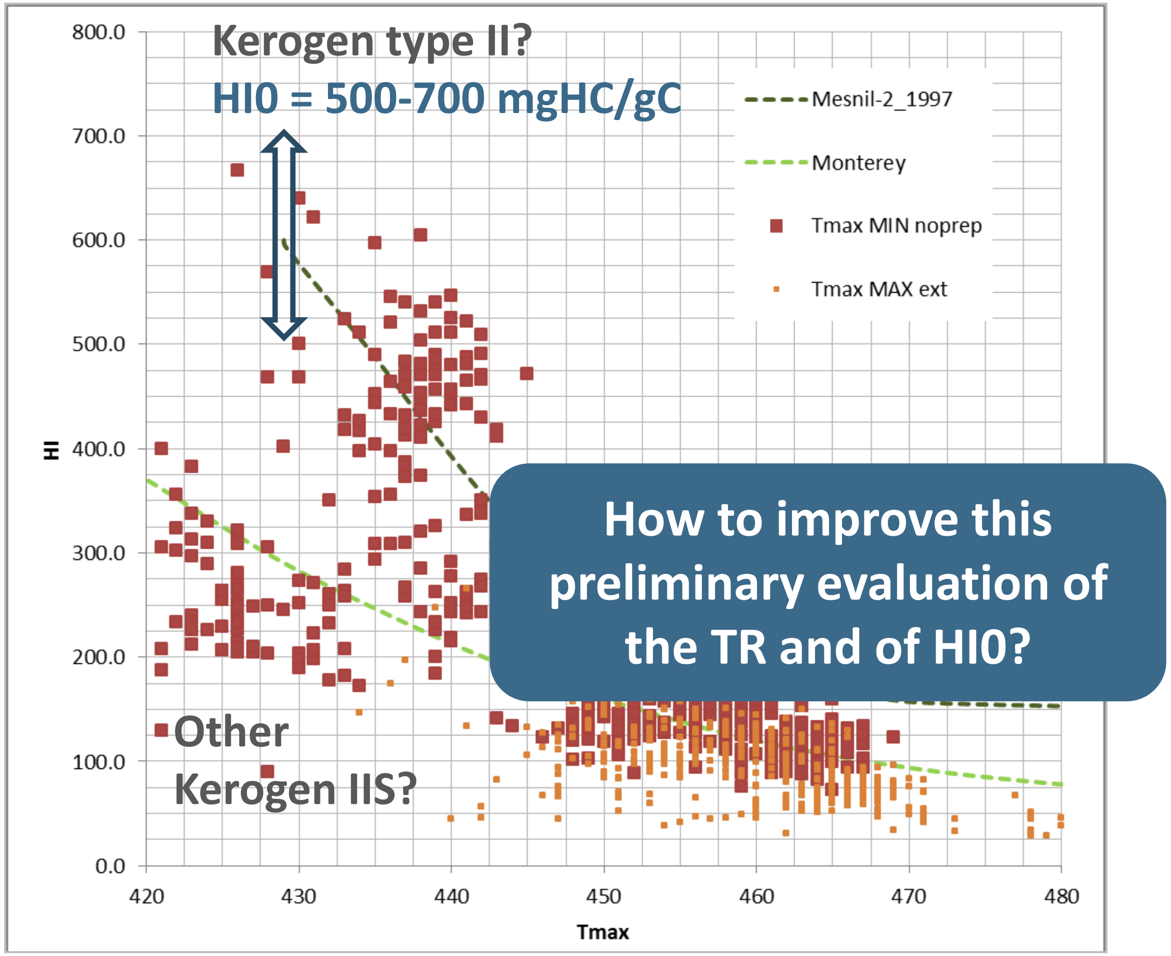
@Beicip-Franlab

Preliminary Initial Pot. Assessment

- A minimal transformation ratio can be calculated (TRmin = S1 / S1+S2 corrected)
- Hypothesis on HI0 can be proposed on the basis of HI vs. Tmax plots (for example), and the corresponding Transformation Ratio TR = f(HI/HI0) can be compared to TRmin and observed HI.

TRmin ~ 45%

	RESULTS 1 / corrected & recalculated DATA		
	mgHC/gR	mgHC/gR	%
	t S2 EXTRACTED EQUIV.	t S1 total	TRt MIN calculated with S1 /S1+S2 (if no HC input)
sample 1	9.1	0.1	
sample 1	5.7	7.9	47%
sample 2	11.4	0.2	
sample 2	10.3	12.1	42%
sample 3	3.4	0.1	
sample 3	2.9	3.5	42%
sample 4	2.1	0.1	
sample 4	2.1	2.3	40%
sample 5	2.3	0.1	
sample 5	2.8	3.3	41%
sample 6	1.3	0.1	
sample 6	1.7	2.2	45%
sample 7	1.4	0.1	
sample 7	1.7	2.2	45%



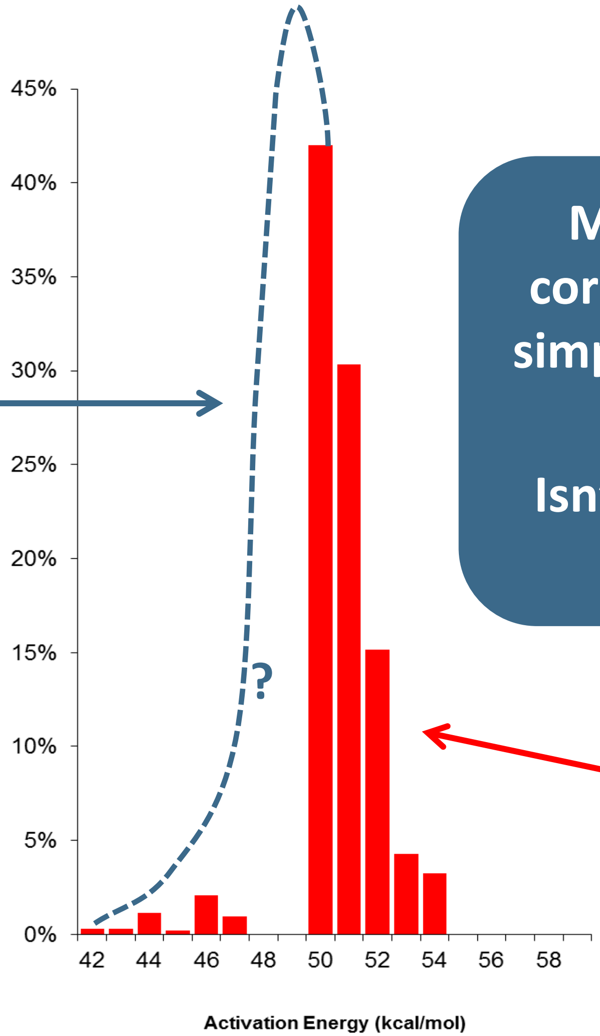
@Beicip-Franlab

Kinetic Database **Observation**

- Bulk kinetic schemes are important data for performing geochemical modeling… but like pirolysis data, measured schemes are not representative of the initial SR potential and should be restored.

Very asymmetric kinetic scheme: it is certainly a mature sample.

Initial kinetic scheme to be reconstructed



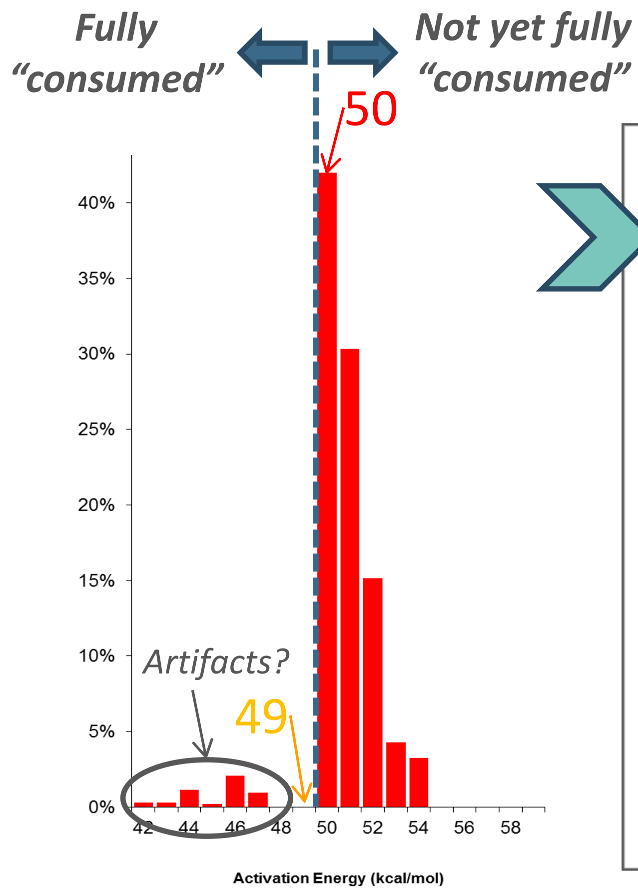
Most of the time, kinetic schemes corresponding to mature samples are simply rejected and analog kinetics are often used in replacement…

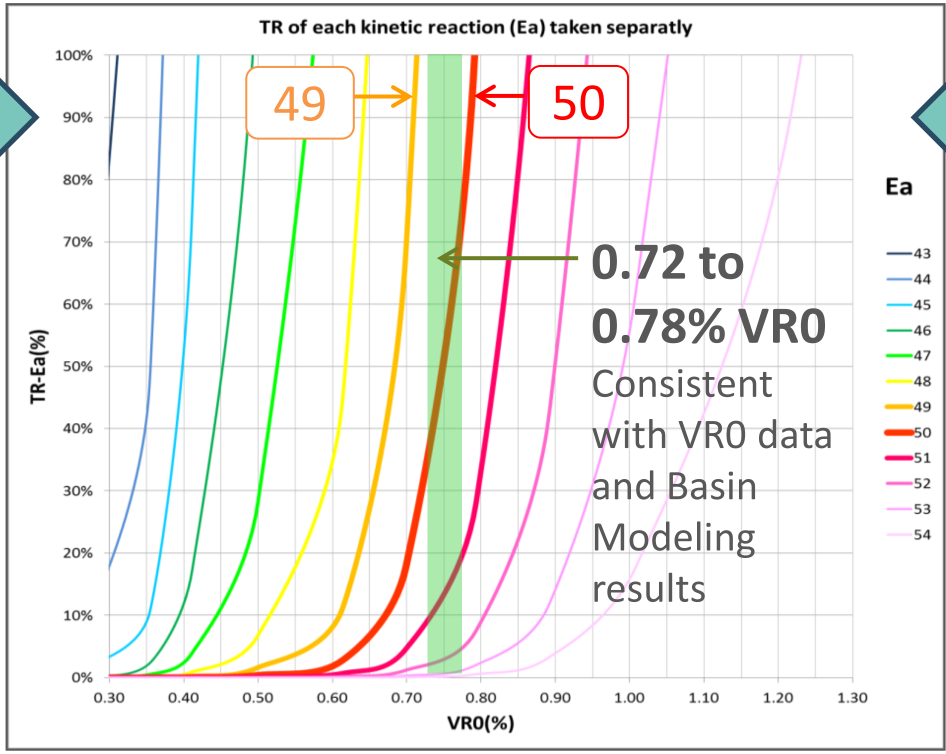
Isn't it possible to reconstruct kinetic schemes?

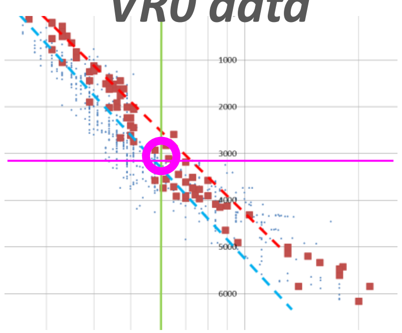
Measured kinetic scheme

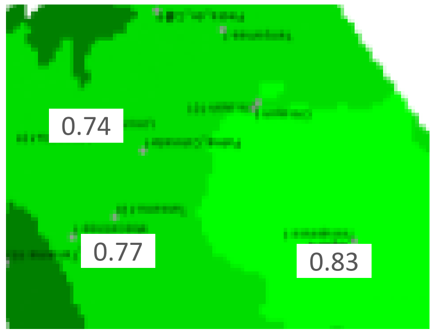
@Beicip-Franlab

Kinetic Scheme: Maturity Check









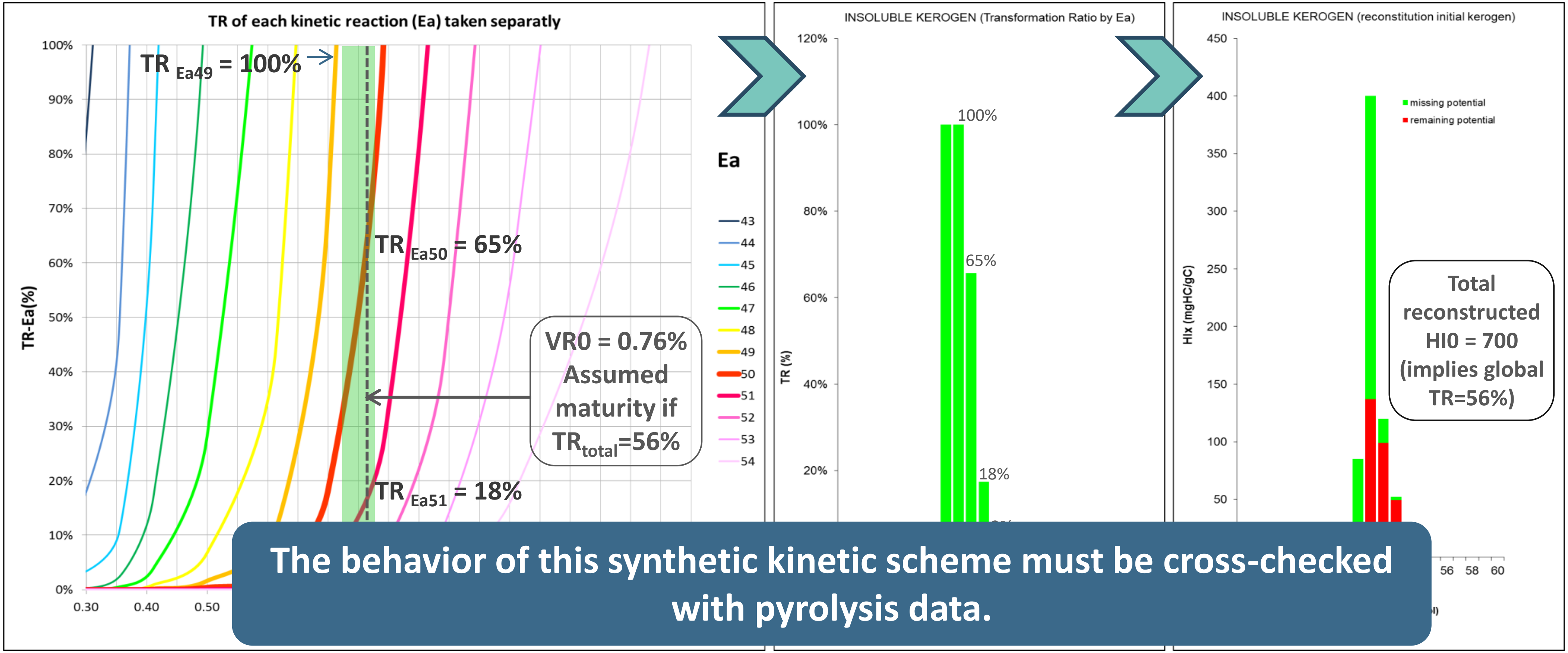
VR0 Basin Model

- Supposing that chemical reactions represented by **Ea 49** are fully achieved, while the ones represented by **Ea 50** are not (TR>30%), then an absolute maturity level of 0.72 to 0.78% VR0 can be postulated.
- This maturity level is compatible with VR0 measurements or basin modeling results.

@Beicip-Franlab

Kinetic Scheme **Reconstruction**

- With the triple constraint of the **VR0**, the **initial HI0 (and TR)**, and the partial **TR_{Ea}** calculated for each activation energy (which is estimated from the maturity level), it is possible to rationally reconstruct «missing» activation energies. There is no unique solution, however the methodology drastically reduces the number of possibilities.

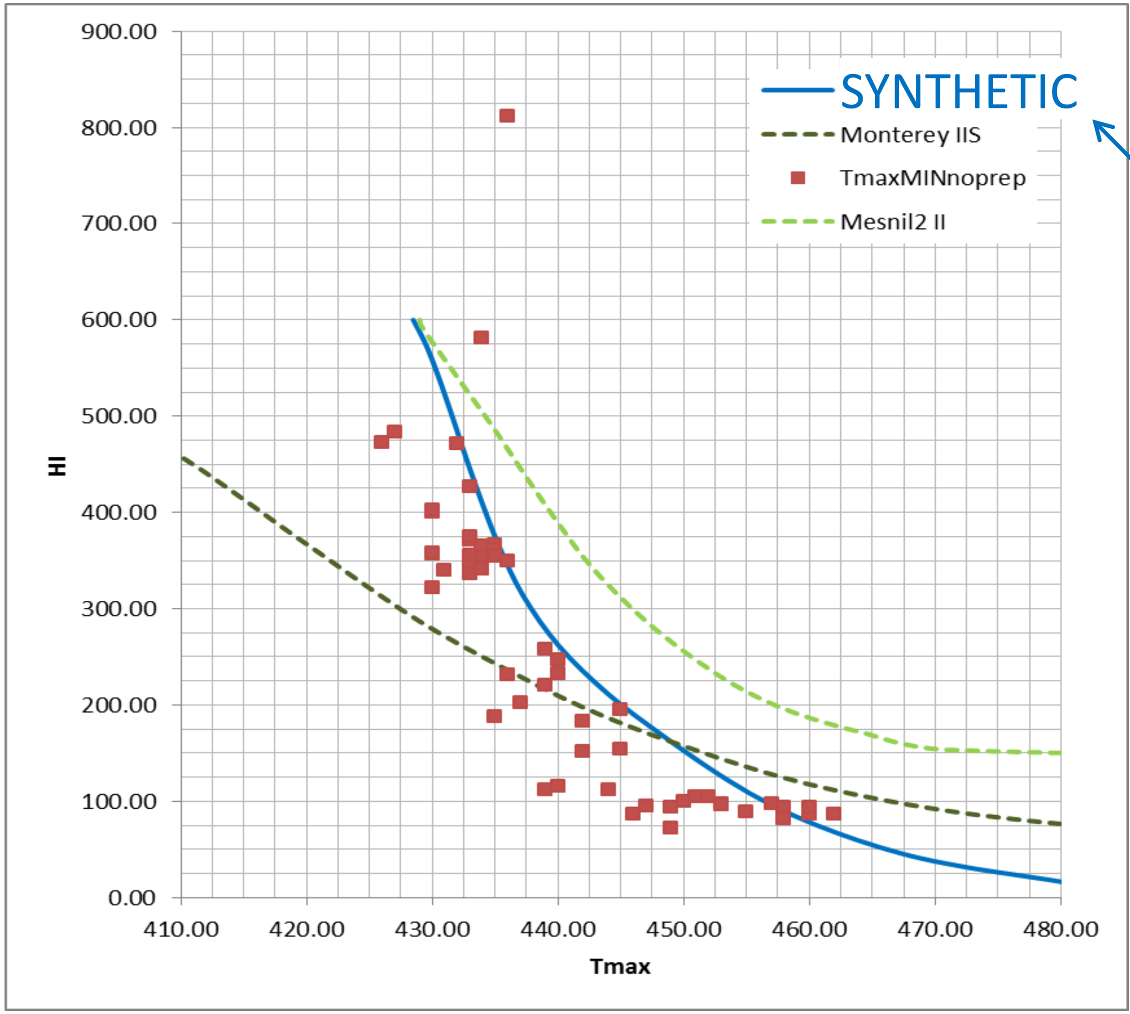


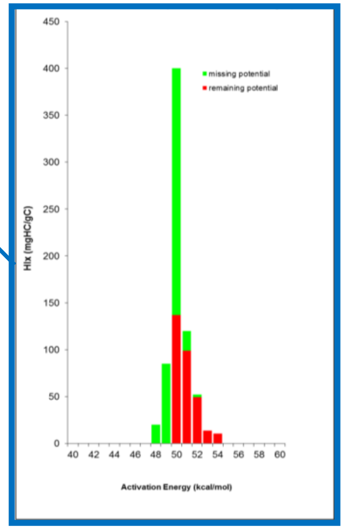
The behavior of this synthetic kinetic scheme must be cross-checked with pyrolysis data.

@Beicip-Franlab

Synthetic Kinetic **Check** – Tmax/HI

- Use of a geochemical simulator for re-computing pyrolysis results corresponding to a given kinetic scheme (initial kinetic scheme + HI_0 → $Tmax_t$, TR_t, HI_t, TOC_t, $VR0_t$, etc.)





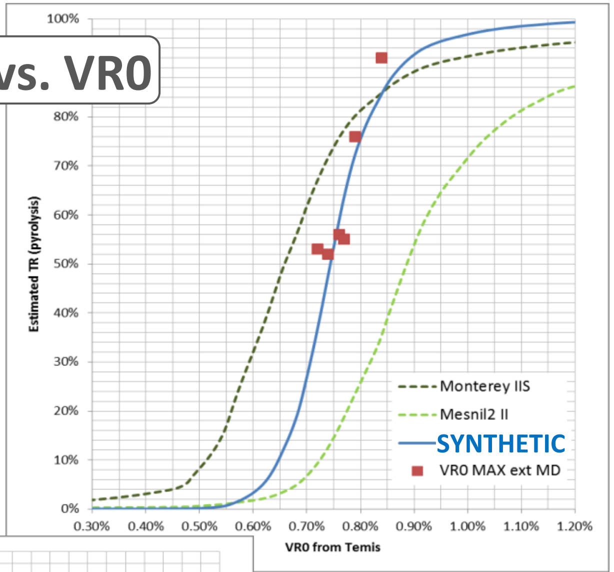
Initial « synthetic » kinetic scheme (reconstructed)

@Beicip-Franlab

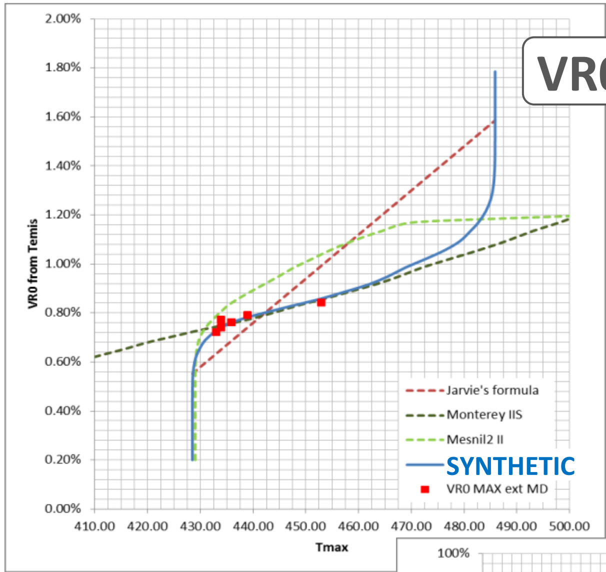
Synthetic Kinetic **Check** – Other Plots

- The synthetic kinetic scheme is validated if it matches pyrolysis and maturity data, basin modeling results, in all the plots… which is not obvious!

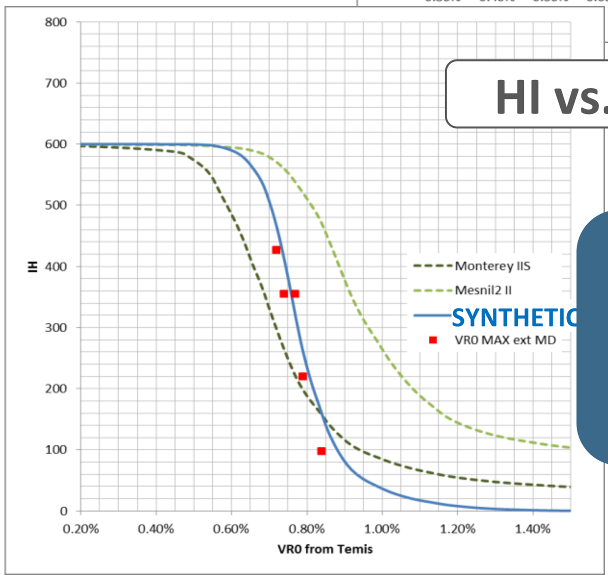
TR vs. VR0



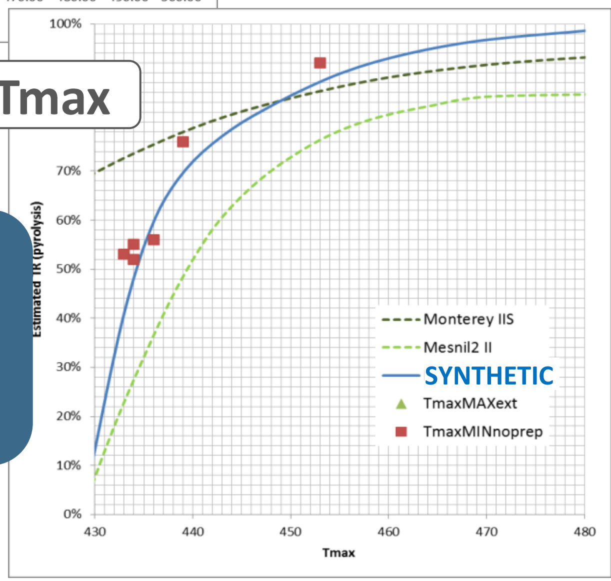
VR0 vs. Tmax



HI vs. VR0



TR vs. Tmax



The kinetic scheme is cross-validated with maturity and pyrolysis data.

What about TOC0?

@Beicip-Franlab

TOC0 Assessment at Well Location

- After cross checking pyrolysis results and kinetic schemes, there is a **reasonable range for HI0 and TR.** Hypothesis can be formulated to assess what would be the corresponding initial TOC0

Hypothesis on HI0 or TR

Algorithm based on mass balance

	RESULTS 1 / corrected & recalculated DATA					RESULTS 2 / initial SR potential					
	gC/gR	mgHC/gTOC	mgHC/gR	mgHC/gR		%	mgHC/gTOC	mgHC/gR	%	gC/gR	gC/gR
Mean	1.6%	193	3.1	2.3		47%	427	10.3	60%	2.3%	2.3%
Mean if EXT	1.6%	176	3.1	0.1			408	10.3	60%	2.4%	2.4%
Mean if NOPREP	1.6%	208	3.1	4.1		47%	443	10.4	60%	2.3%	2.3%
	t TOC EXTRACTED EQUIV.	t HI EXTRACTED EQUIV.	t S2 EXTRACTED EQUIV.	t S1 total	HYPOTHESIS on TR or HI0	TRt MIN calculated with S1 /S1+S2 (if no HC input)	HI0	S20	TRt	TOC0	TOCf (ultimate)
sample 1 (EXT)	3.8%	239	9.1	0.1	TR = 60%	47%	341	17.8	60%	5.2%	3.2%
sample 1	4.1%	137	5.7	7.9	TR = 60%		483	36.3	60%	7.5%	3.6%
sample 2(EXT)	5.1%	224	11.4	0.2	TR = 60%	42%	492	32.0	60%	6.5%	4.0%
sample 2	4.6%	224	10.3	12.1	TR = 60%		440	10.8	60%	2.5%	4.9%
sample 3 (EXT)	1.7%	195	3.4	0.1	TR = 60%	42%	412	9.3	60%	2.3%	4.1%
sample 3	1.7%	175	2.9	3.5	TR = 60%		429	6.7	60%	1.6%	1.6%
sample 4 (EXT)	1.1%	188	2.1	0.1	TR = 60%	40%	460	6.5	60%	1.4%	1.5%
sample 4	1.0%	204	2.1	2.3	TR = 60%		458	7.3	60%	1.6%	1.0%
sample 5 (EXT)	1.1%	207	2.3	0.1	TR = 60%	41%	574	8.8	60%	1.5%	0.9%
sample 5	1.0%	282	2.8	3.3	TR = 60%		406	4.3	60%	1.1%	1.0%
sample 6 (EXT)	0.8%	174	1.3	0.1	TR = 60%	45%	498	5.3	60%	1.1%	0.8%
sample 6	0.7%								60%	1.0%	0.7%
sample 7 (EXT)	0.7%								60%	1.1%	0.6%
sample 7	0.7%										

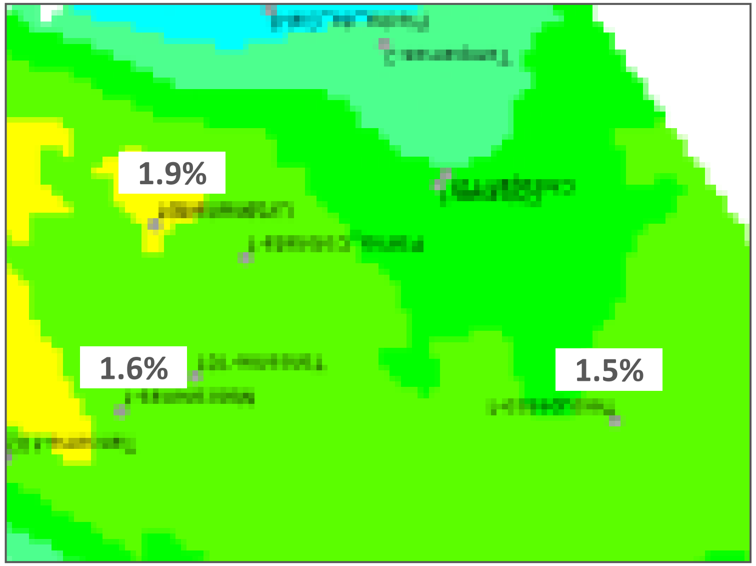
Now we have everything for the geochemical modeling

@Beicip-Franlab

Initial TOC0 Mapping vs. Present TOC

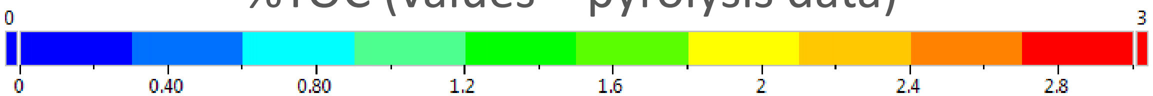
- The **initial TOC0** at well location can be mapped taking into account well constraints as well as geological / sedimentary concepts. Do not extrapolate TOCt maps!
- Then TOC0 maps as well as other geochemical data are implemented in a basin model…

TOCt (observed at present day)



Model OUTPUT

%TOC (values = pyrolysis data)

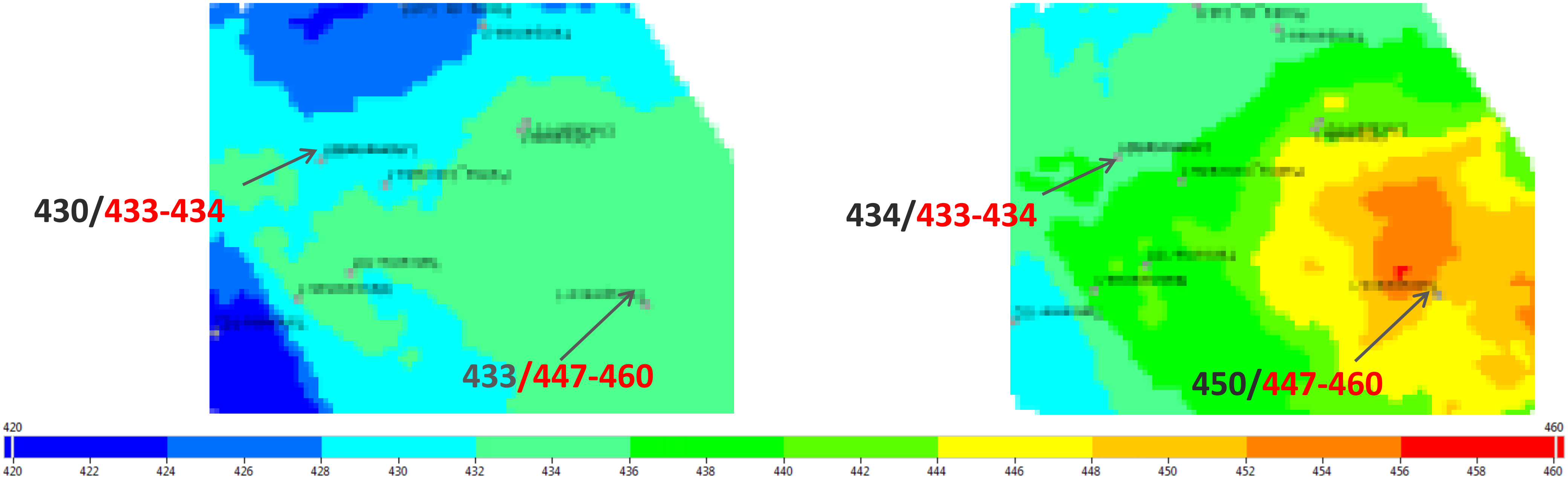


@Beicip-Franlab

Comp. with Other Kinetics – Tmax

- What would be the **Tmax** calculated with the basin model if the « analog » kerogen initially selected had been used?

Menil-2 kinetic scheme (reference Type II) | **Synthetic** kinetic scheme (reconstructed – this study)



Tmax [°C] calculated by TemisFlow (black) / pyrolysis (red)

Much better calibration of the relative maturity level with the “synthetic” kinetic scheme.

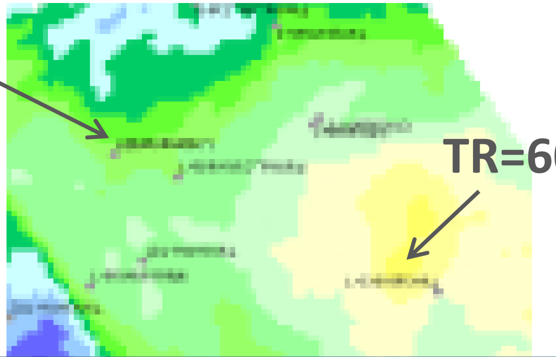
@Beicip-Franlab

Comp. with Other Kinetics – TR (%)

- What would be the **Transformation Ratio** (TR) calculated with the basin model if the « analog » kerogen initially selected had been used?

Menil-2 kinetic scheme
(reference Type II)

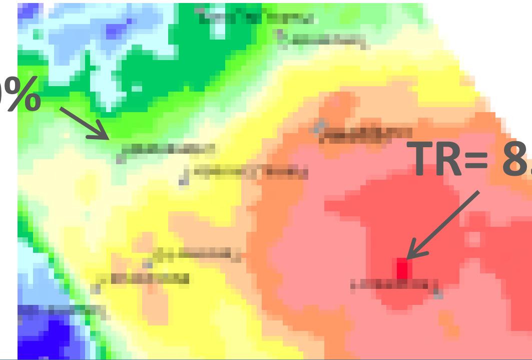
TR = 40%



TR=60%

Synthetic kinetic scheme
(reconstructed – this study)

TR=50%



TR= 85 %

In this example, the TR is 10-25% higher than initially expected with the “reference” kinetic scheme: as many additional HC resources in the basin… without even mentioning the additional HC linked to the correction of pyrolysis data!

- Ultimate objectives are often resource assessment in terms of volumes and fluid quality
  - Model shows good calibration to °API and GOR measurements

@Beicip-Franlab

Conclusions (1/2)

- Initial source rock potential and kinetics reconstruction:

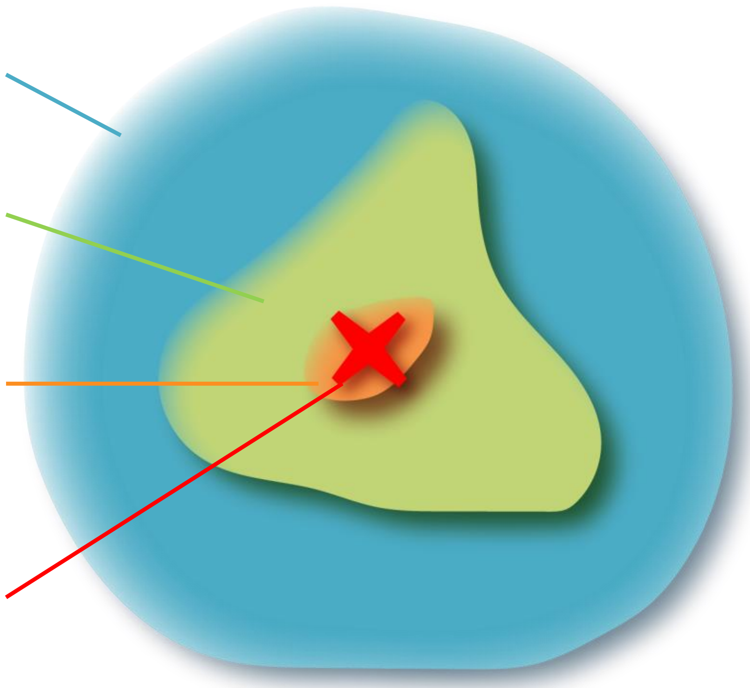
Uncertainty reduction

Natural geochemical variability

Calibrated with ***homogenized pyrolysis data***

Calibrated with ***rebuilt initial kinetics,*** *crosschecked with pyrolysis data*

Proposed geochemical model *within the reduced range of possibilities*



The workflow is not straightforward and not magical: it does not always work as well as in presented examples, and kinetic schemes interpretation may be tricky.

Still, it is necessary to try to integrate all the data: the result will be better than the use of poorly constrained analogs.

@Beicip-Franlab

Conclusions (2/2)

- Do not get rid of strange data before checking if the dataset can be homogenized
  - These data may bring something
- Integrate and crosscheck all available data. There are narrow relationships between pyrolysis and kinetic dataset that must be explored
  - There is only a reduced number of possible combinations
- In the case of studied Upper Jurassic kerogens, carbonate-rich, this workflow has demonstrated that the source rocks have generated much more hydrocarbons than what was initially predicted
  - **It led to the reevaluation of the yet-to-find in studied basins**

Thank you for your attention!

matthieu.dubille@beicip.com

@Beicip-Franlab