

PS Integrated Stratigraphic and Petroleum System Modeling Study of the Southern Upper Rhine Graben*

Stéphane Roussé¹, Pierre-Yves Filleaudeau¹, Guillaume Cruz Mermey¹, Alexandre Letteron², and Marc Schaming³

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¹Beicip-Franlab, Rueil Malmaison, France (pierre-yves.filleaudeau@beicip.com)

²IFPen, Rueil Malmaison, France

³Institut de Physique du Globe, Strasbourg Cedex, France

Abstract

The Upper Rhine Graben (URG) is a Tertiary rift located between the Vosges (France) and Black-Forest (Germany) Variscan units as a part of the European Cenozoic Rift System (ECRS), which crosses Western Europe from the Mediterranean Sea to the North Sea over more than 1000 km. Recent URG structuration started during the Tertiary with a major WNW-ESE extension (Eo-Oligocene) followed by a sinistral strike-slip during Miocene. Its evolution is closely related to the Paleozoic inheritance and Permian highs and troughs structuration. These crustal discontinuities fragmented the URG into several opposing tilt sub-basins separated by wrench faults. Between those periods of active structuration, Triassic and Jurassic sediments are deposited during a relative tectonic quiescence onto the Western European Platform. Active petroleum system in the URG is known since the 15th century. Most of the hydrocarbon production took place in Pechelbronn Field until 1968. Hydrocarbon accumulations are found in the Dogger “Grande Oolithe” Formation and in Oligocene syn-rift clastics reservoirs and overlying thick Tertiary shales. Associated evaporates act as a regional seal. Hydrocarbon generation is linked to the presence of Liassic source rocks (e.g. Sinemurian shales and Toarcian “Schistes Cartons”). In this study, we focused on the southern part of the URG between the cities of Colmar and Belfort (France) and Basel (Switzerland) to assess the maturity of Jurassic source rocks and evaluate the distribution of Meso-Cenozoic reservoirs within Mulhouse Potash Basin to the North and the Dannemerie Basin and Altkirch-Basel tilted-block array to the South. To that aim, an integrated workflow combining well-data synthesis and correlation, seismic interpretation, fieldwork, forward stratigraphic modeling (DionisosFlow®) and thermal basin modeling (TemisFlow®) was used. Tertiary sequences were investigated through stratigraphic modeling in order to provide 3D spatial distribution of the distinctive sedimentary facies, predicting occurrences of the potential Tertiary reservoir/seal couplets. Petroleum system modeling was carried out on two 2D sections integrating previous results. Thermal and maturity calibration were obtained by modeling the whole lithosphere and heating caused by Tertiary rifting events. The calibration also highlights the importance of hydrothermal circulation in the generation of hydrocarbons that migrates to known accumulation of Staffelfelden.

References Cited

Blanc-Valleron, M.-M., 1990, Les formations paléogènes évaporitiques du bassin potassique de Mulhouse et des bassins plus septentrionaux d'Alsace: Ph.D. dissertation, Louis Pasteur University, Strasbourg. 350 p.

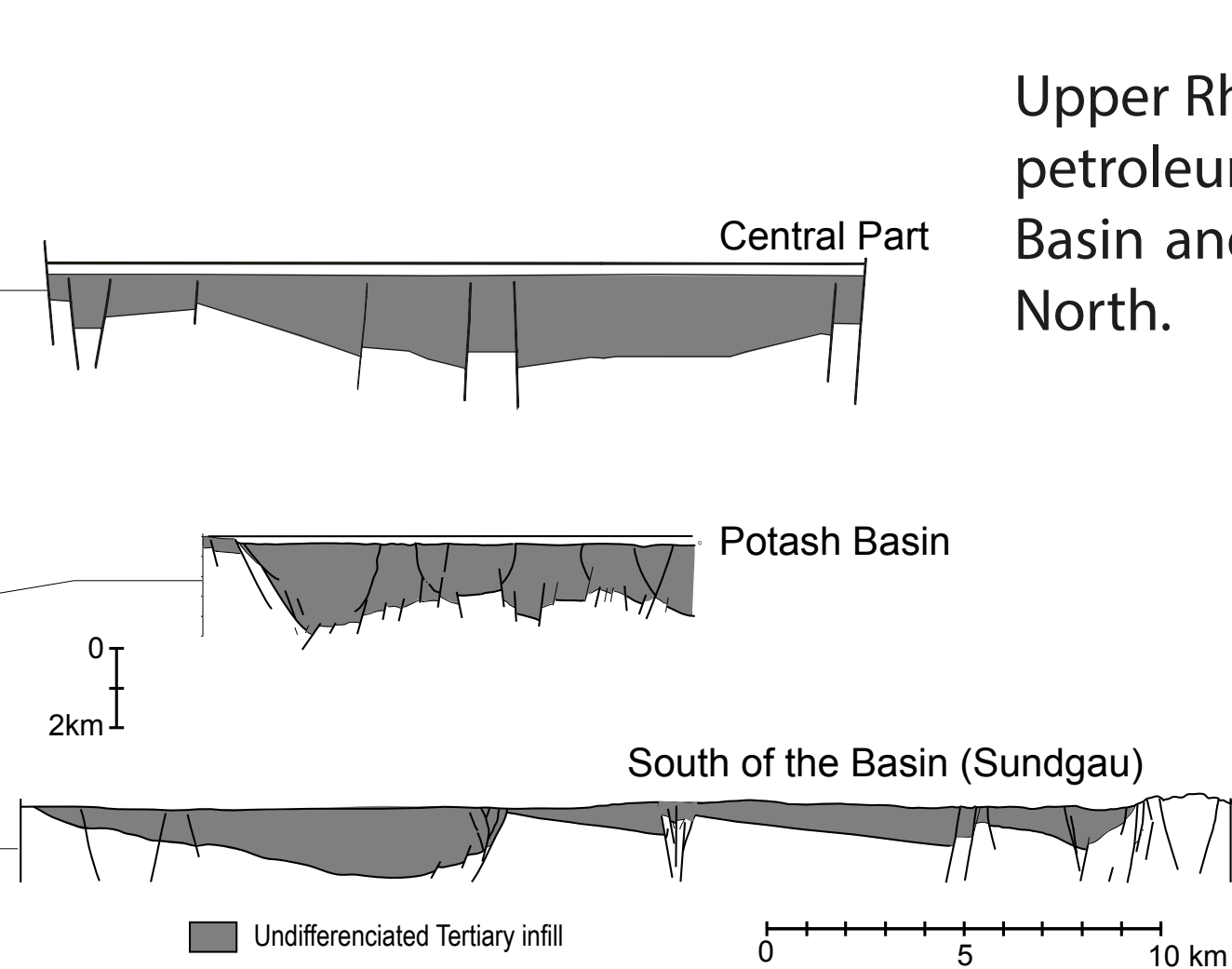
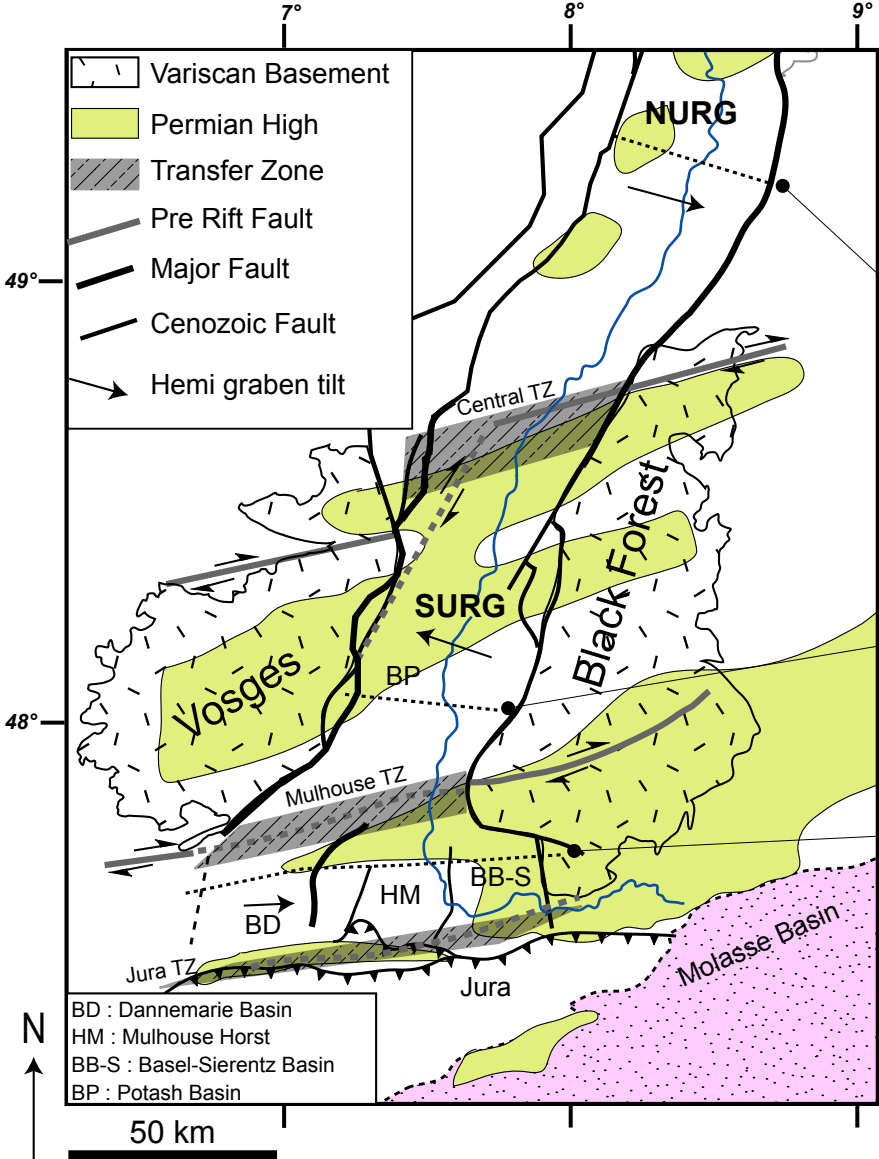
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Van Hinsbergen, D.J.J., L.V. de Groot, S.J. van Schaik, W. Spakman, P.K. Bijl, A. Sluijs, C.G. Langereis, and H. Brinkhuis, 2015, A Paleolatitude Calculator for Paleoclimate Studies: PLoS ONE, v. 10/6, e0126946. doi:10.1371/journal.pone.0126946.

Wygrala, B.P., 1989, Integrated study of an oil field in the southern Po basin, northern Italy: Ph.D. dissertation, Köln University: Jülich, Research Centre Jülich, Jul-Rep. 2313, ISSN 0366-0885, 217 p.

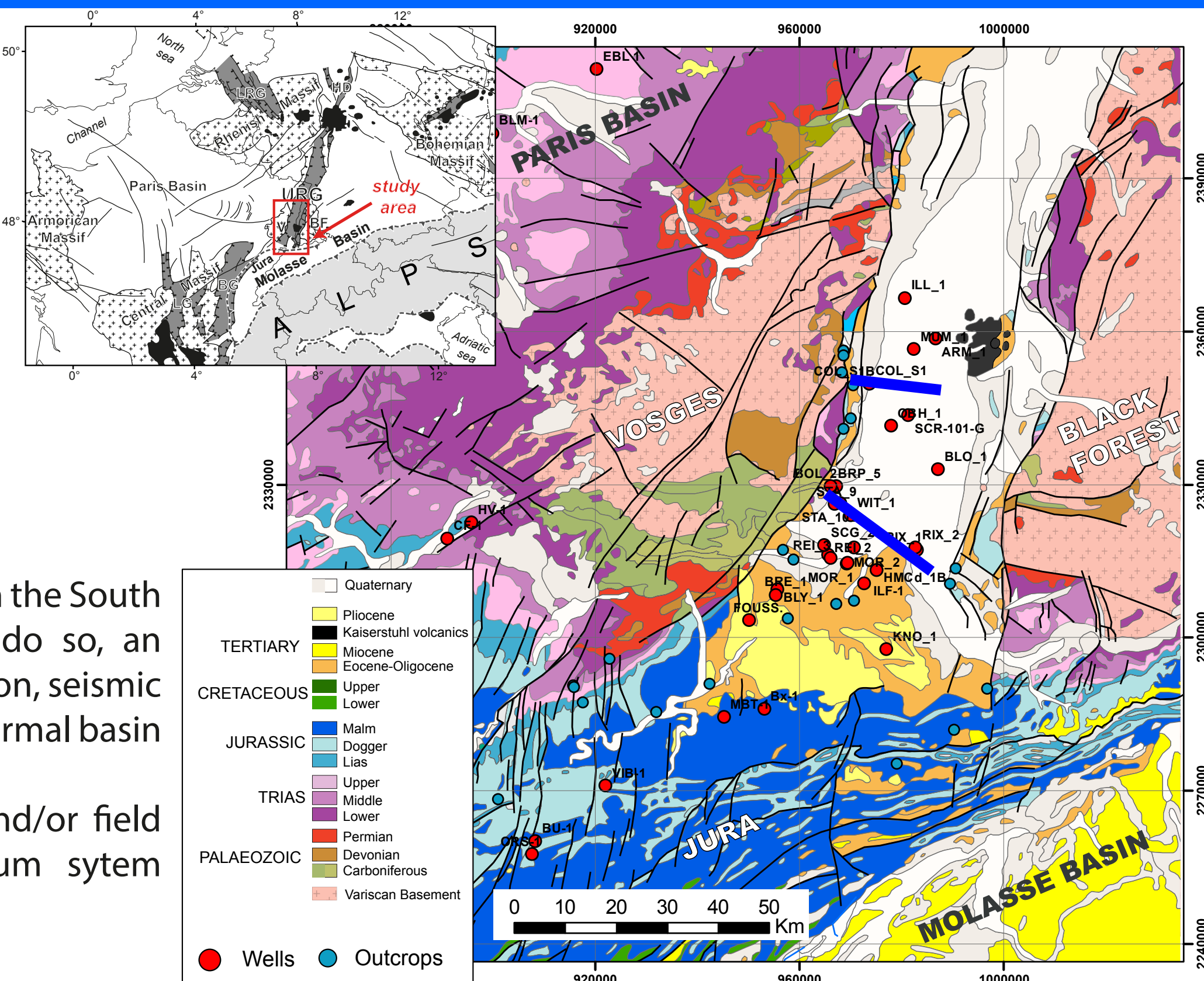
INTRODUCTION AND REGIONAL SETTING

The Upper Rhine Graben (U.R.G.) is a Tertiary rift located between the Vosges (France) and Black-Forest (Germany) Variscan units as part of the European Cenozoic Rift System (ECRS). Recent Rhine Graben structuration started during the Tertiary, first with a major WNW-ESE extension (Eo-Oligocene) and then with a sinistral strike-slip reactivation during Miocene which is responsible for the actual morphological expression of the rift. However, its evolution is closely related to Paleozoic inheritance resulting in Permian highs and troughs structuration (Roussé, 2006 and references herein).

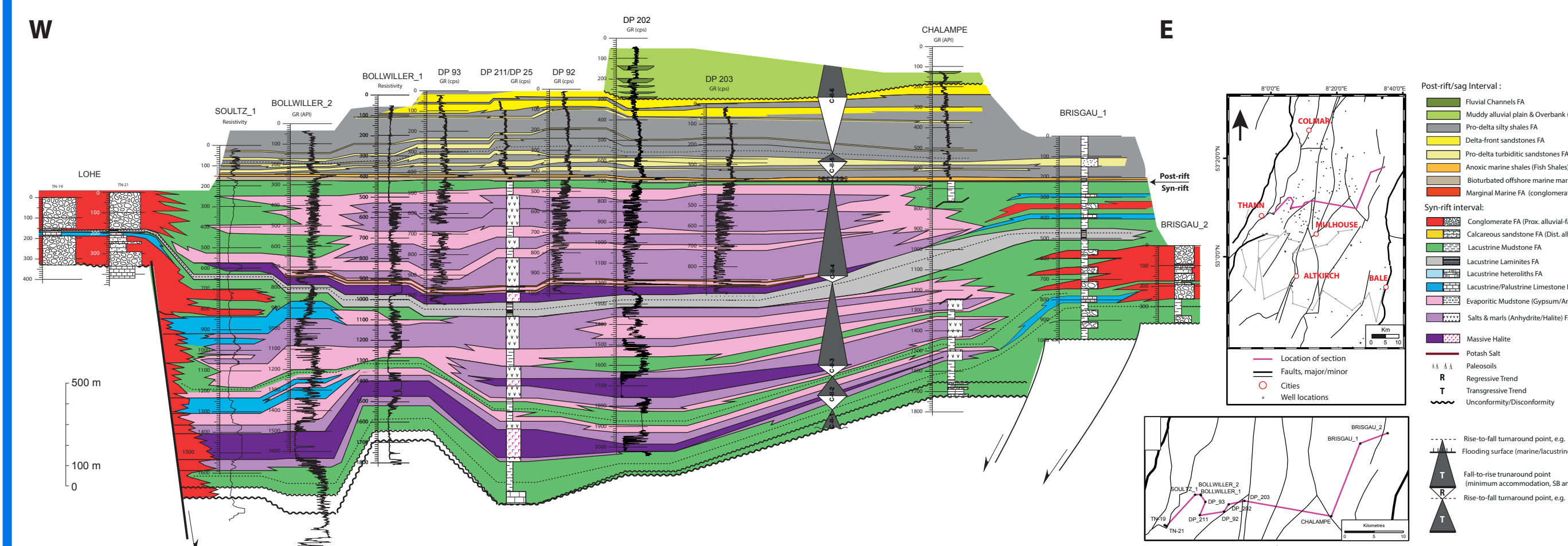


Upper Rhine Graben is an easy access analog for rift systems in the aim of petroleum exploration with numerous available well data in Mulhouse Basin and active petroleum system reported in Pechelbronn field to the North.

This study proposes a review of the petroleum system potential in the South of the URG using state-of-art basin modeling softwares. To do so, an integrated workflow combining well-data synthesis and correlation, seismic interpretation, field work, forward stratigraphic modeling and thermal basin modeling was used. This database is continuously fed with new published data and/or field investigations, in order to better characterize key petroleum system elements of the area.



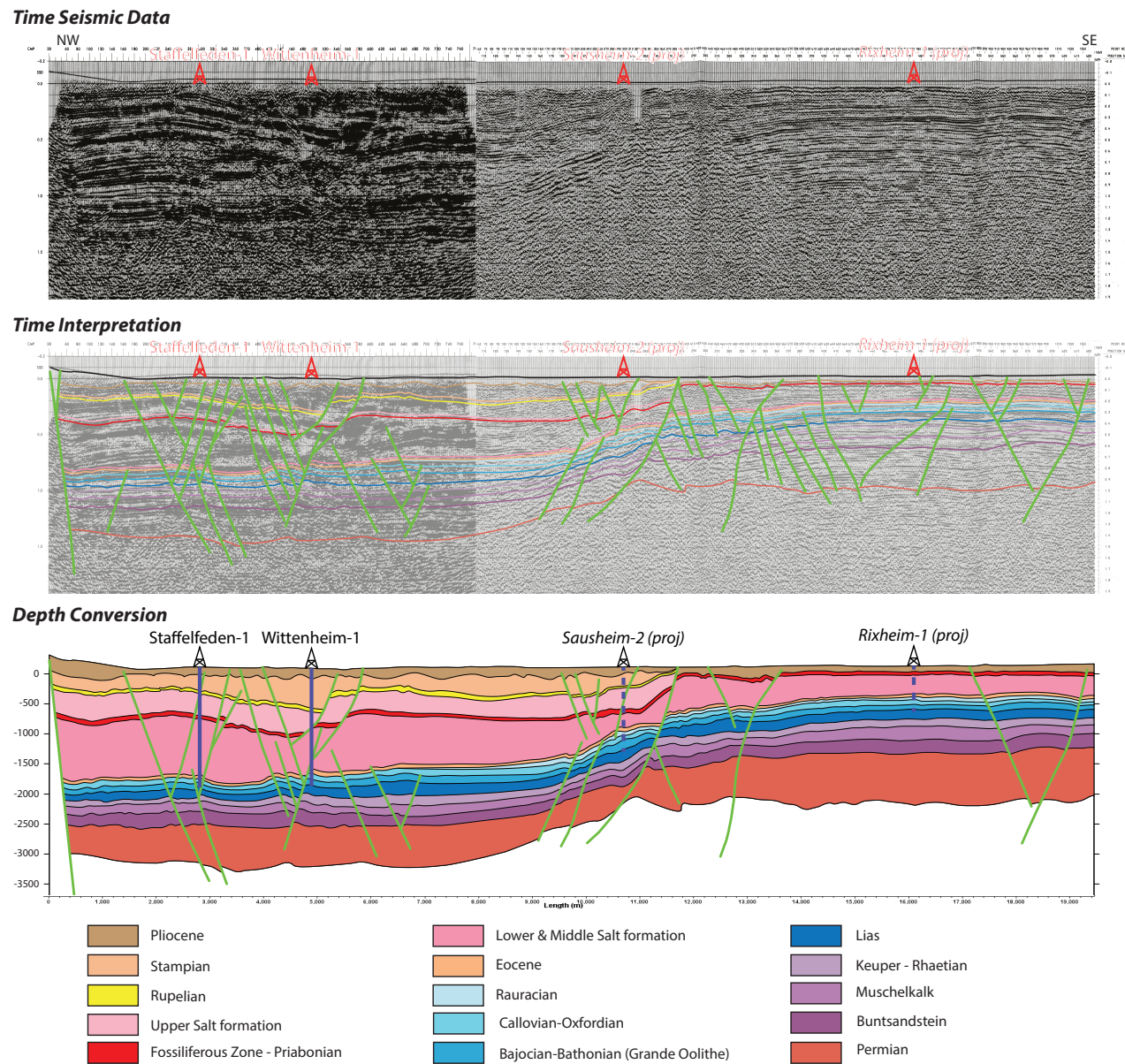
INPUT DATA FOR STRATIGRAPHIC MODELING



Well correlation panels were realized from facies review of drilling reports for both Mesozoic and Cenozoic intervals, allowing to evidence lateral facies variations.

INPUT DATA FOR THERMAL & MIGRATION MODELING

Horizon interpretation

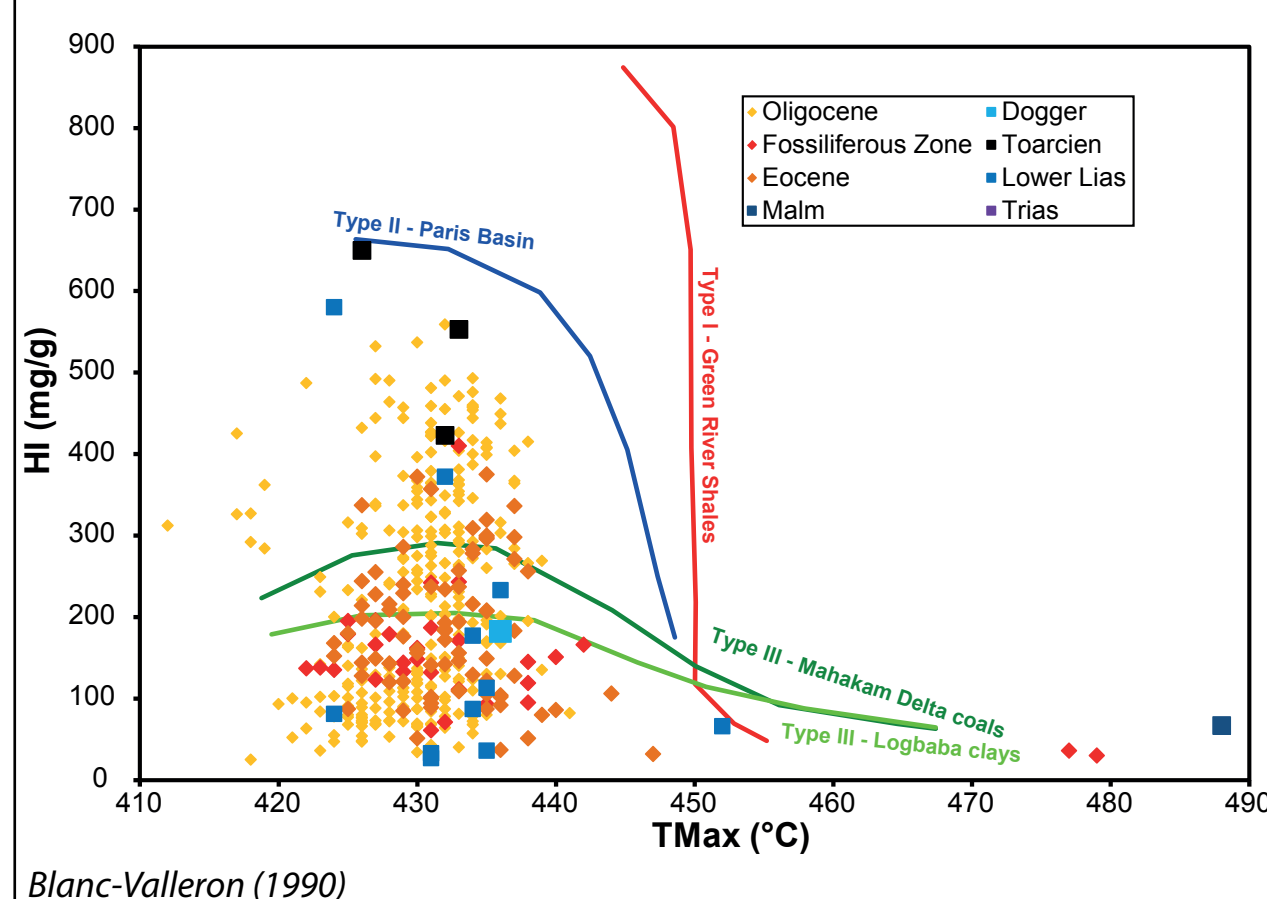


Main markers from the wells were tied to the seismic and propagated in the basin to propose this structural interpretation.

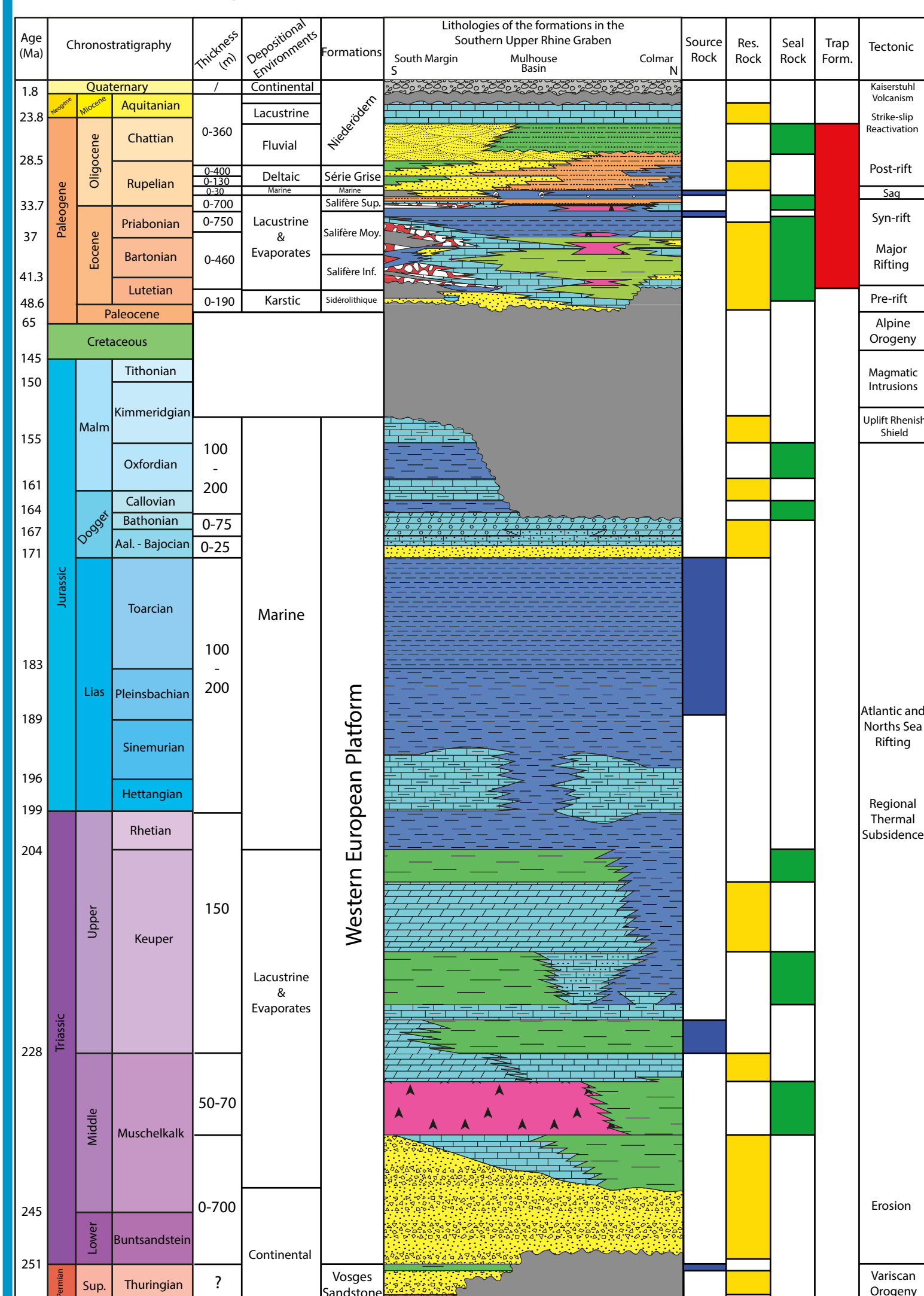
This interpretation was then used as a template for the initial mesh of the basin model

Review of the geochemical data from wells

Four organic-rich levels were evidenced and integrated in the 2D basin models (**Liassic, Toarcian, Fossiliferous Zone and Oligocene**). Jurassic and Oligocene SR were tested with a Type II kerogen (HI = 600 mg HC/g TOC). Fossiliferous Zone is considered as a Type III kerogen with a HI of 200 mg/g. TOC is fair along the sections (2.5 to 3.5 %).



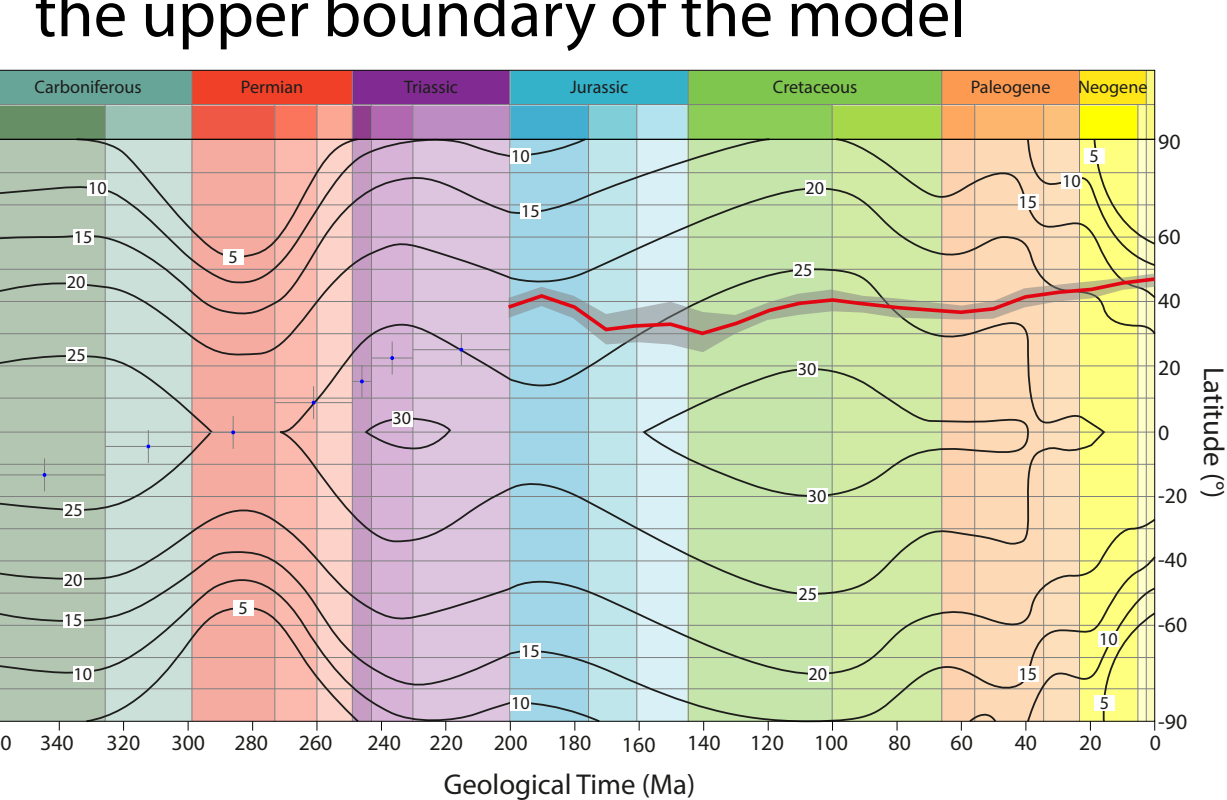
Lithostratigraphic chart of the Southern Upper Rhine Graben



Cenozoic facies distribution updated with the results of the forward stratigraphic modeling



Surface temperature evolution defined as the upper boundary of the model



Mesozoic facies from well correlation panes and outcrop analysis

^a Beicip-Franlab,
232 av Napoléon Bonaparte
92500 Rueil Malmaison, France
stephane.rousse@beicip.com

^b IFPEN
1 & 4, avenue de Bois-Préau
92500 Rueil Malmaison, France

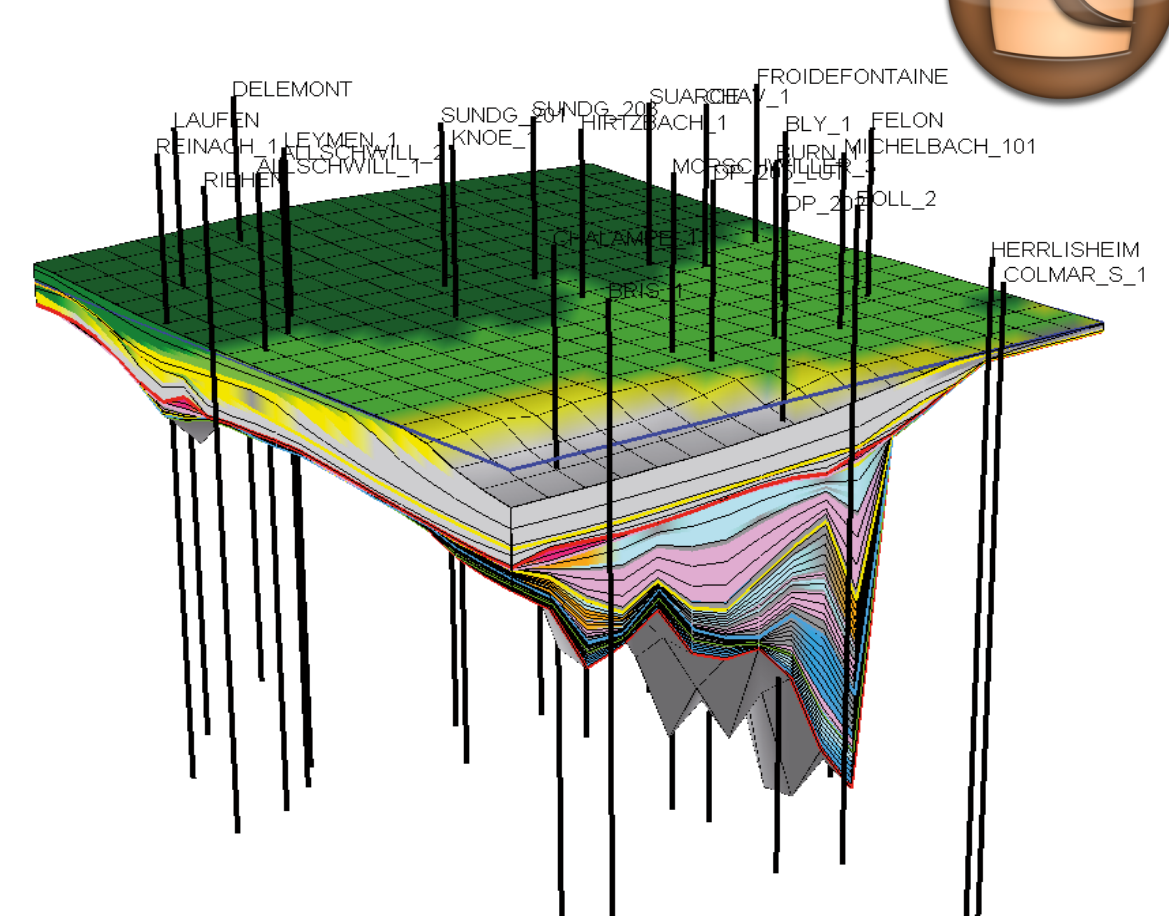
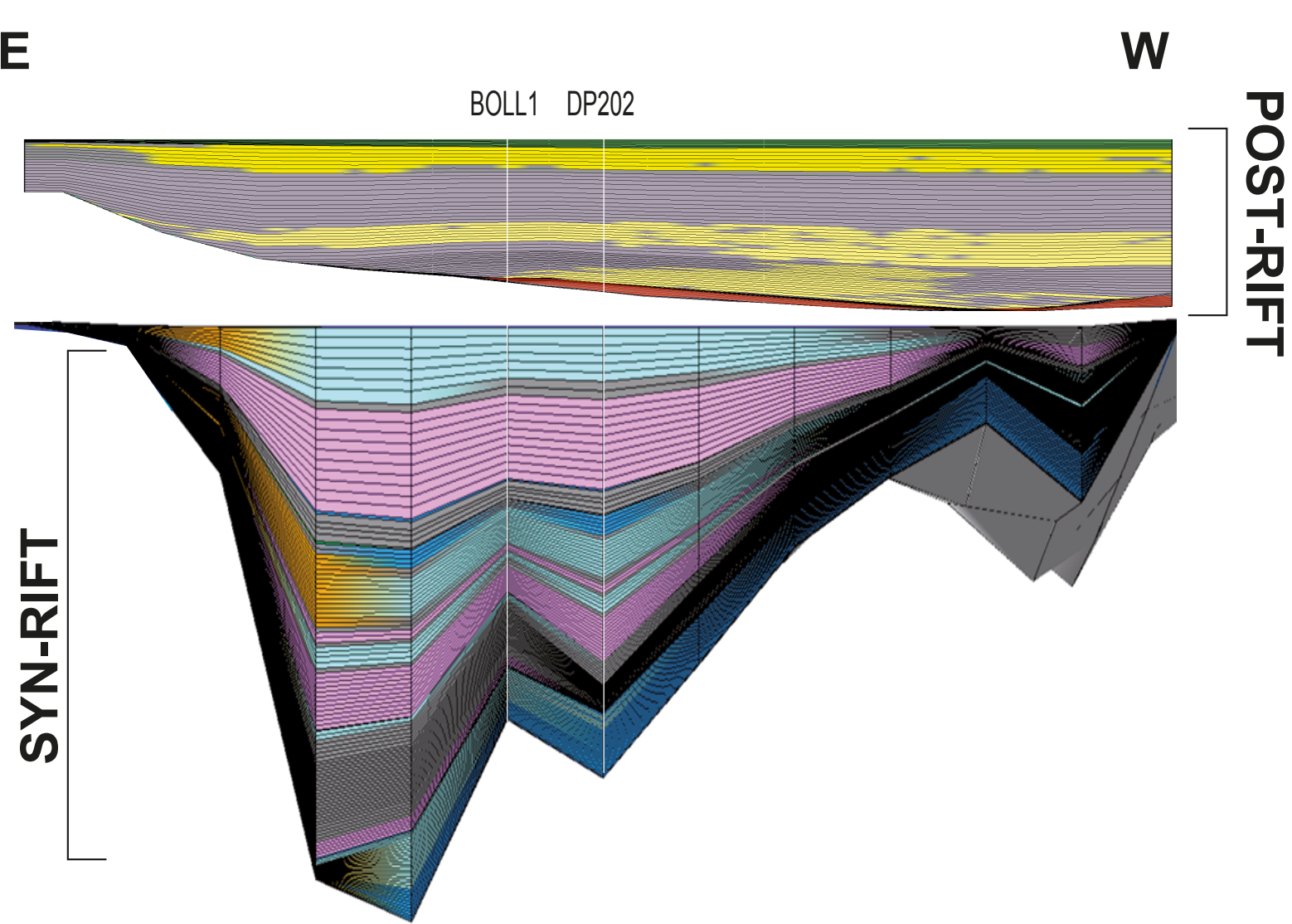
^c Institut de Physique du Globe
5 rue René Descartes
67084 Strasbourg Cedex, France

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RESULTS OF THE STRATIGRAPHIC MODELING

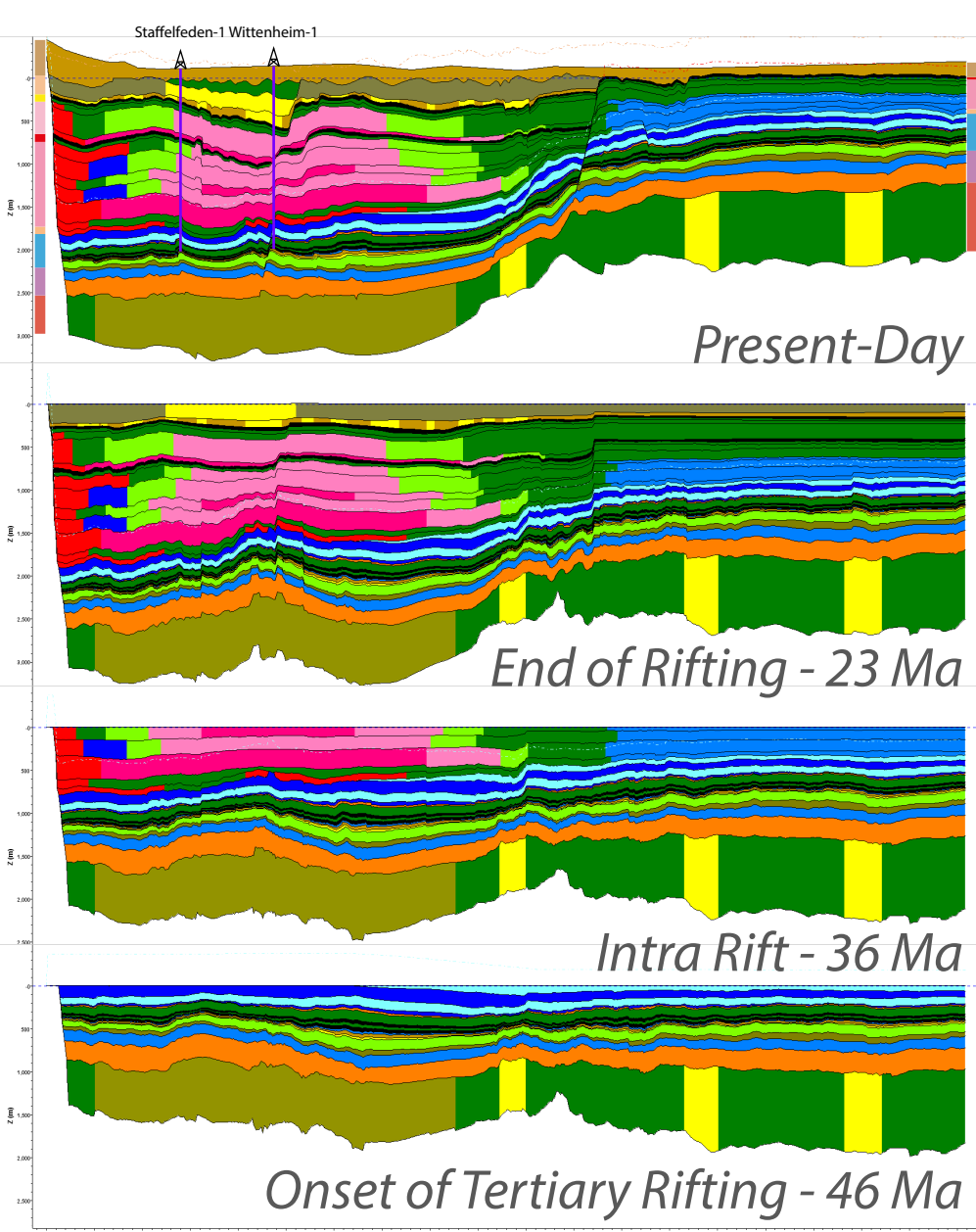
3D forward stratigraphic modeling is handled using the software DionisoFlow that account for **accommodation** (subsidence vs eustasy), **sedimentary supply** (input from erosion vs *in situ* production) and **transport** (diffusive transport laws)



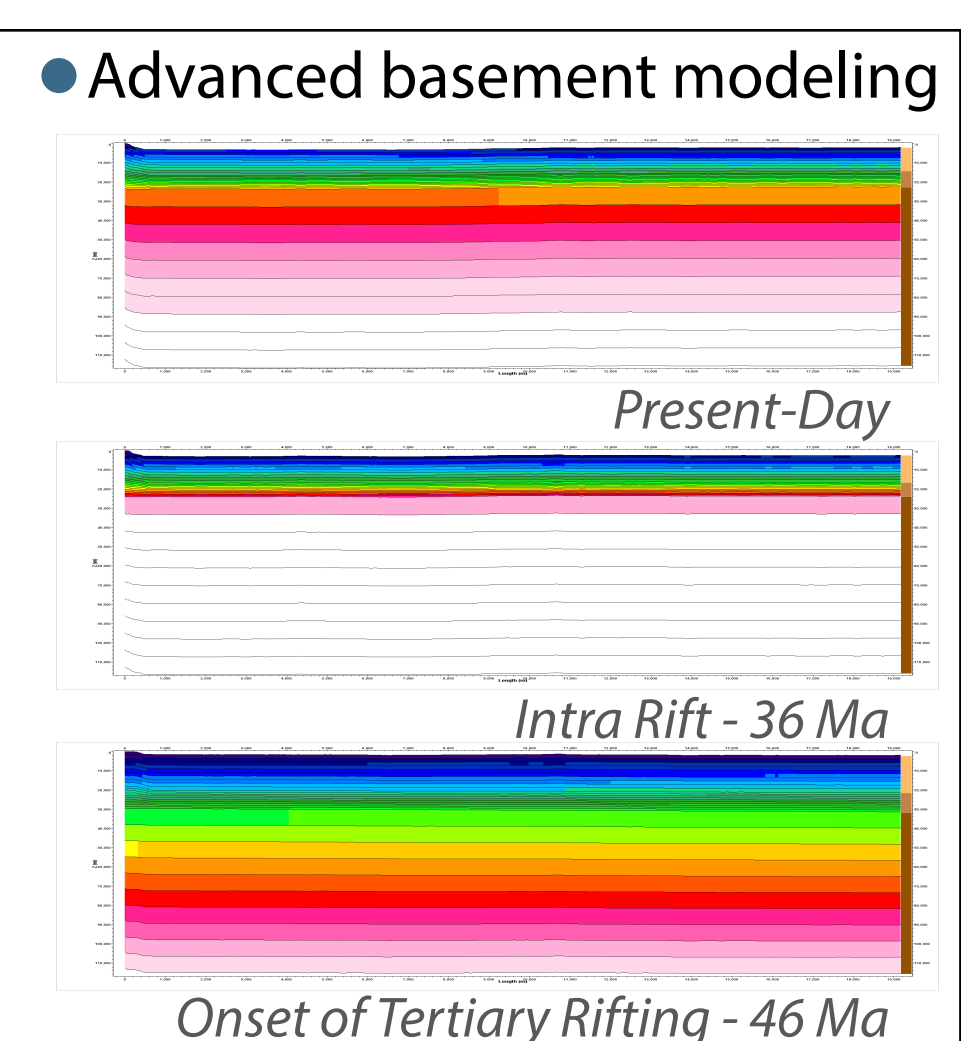
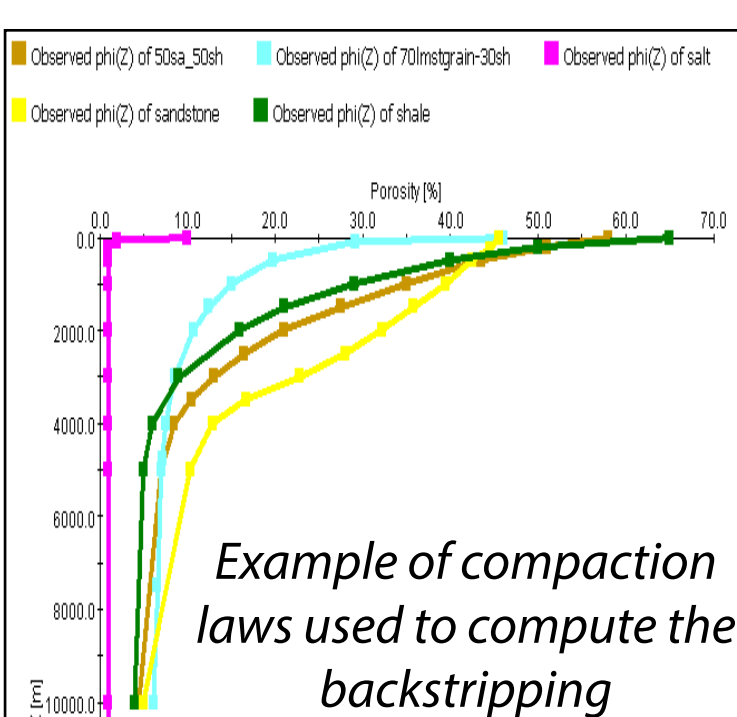
Evaporitic cycles are well reproduced throughout the study area
Sedimentary architecture is respected in the model for both thickness and sequencing.
Nonetheless some uncertainty remain for the facies calibration at well location

RESULTS OF THE THERMAL & MIGRATION MODELING

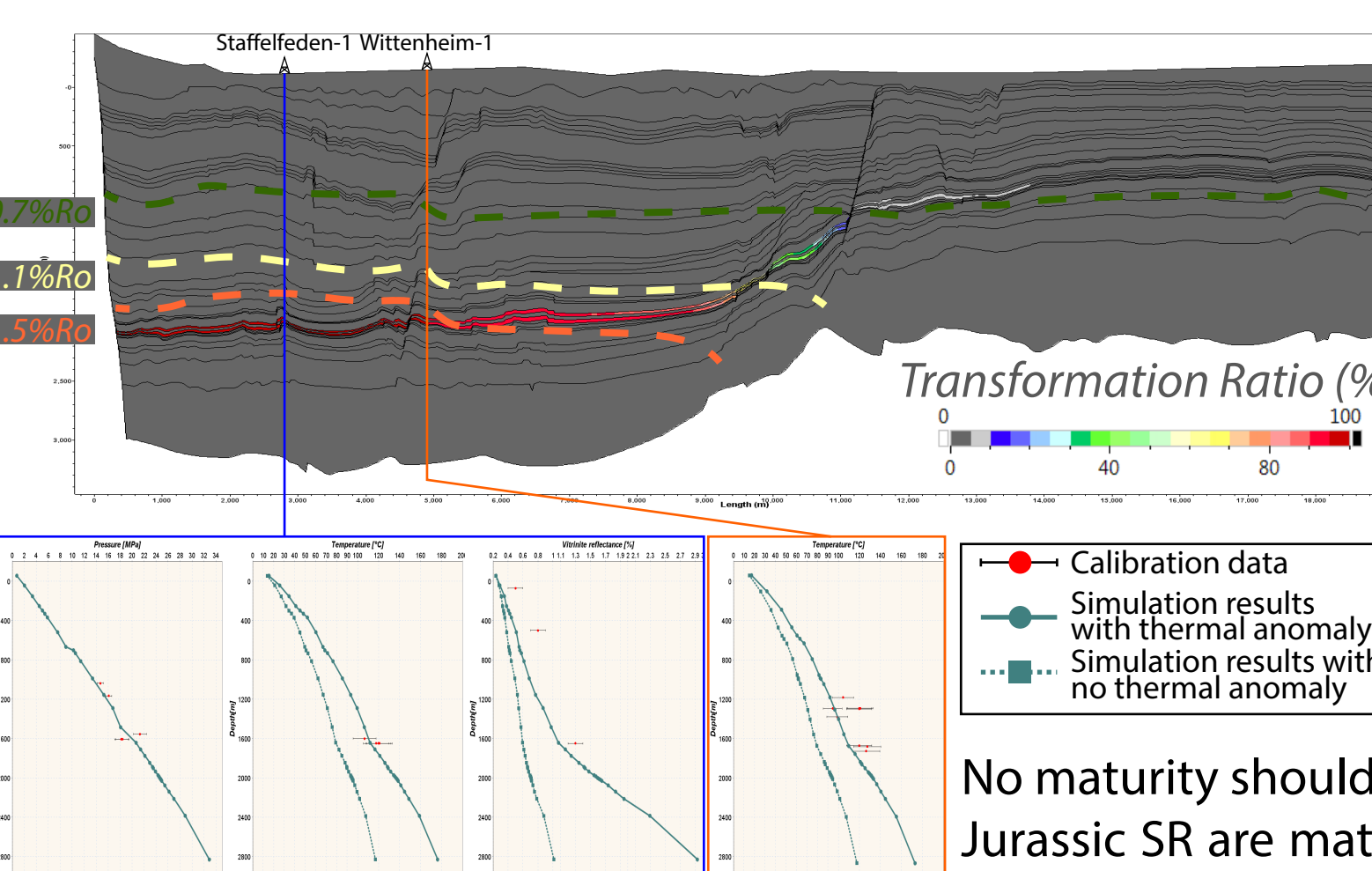
Lithology dress-up and Backstripping



The section is built from converted-to-depth seismic horizon and sublayered to account for all petroleum system elements to be tested.
The model is then populated in facies using well correlation, forward stratigraphic modeling and outcrop interpretation.
Initial geometry is computed using the backstripping algorithm taking into account the porosity vs depth law defined for each facies. Artefacts linked to fault throw are finally smoothed.

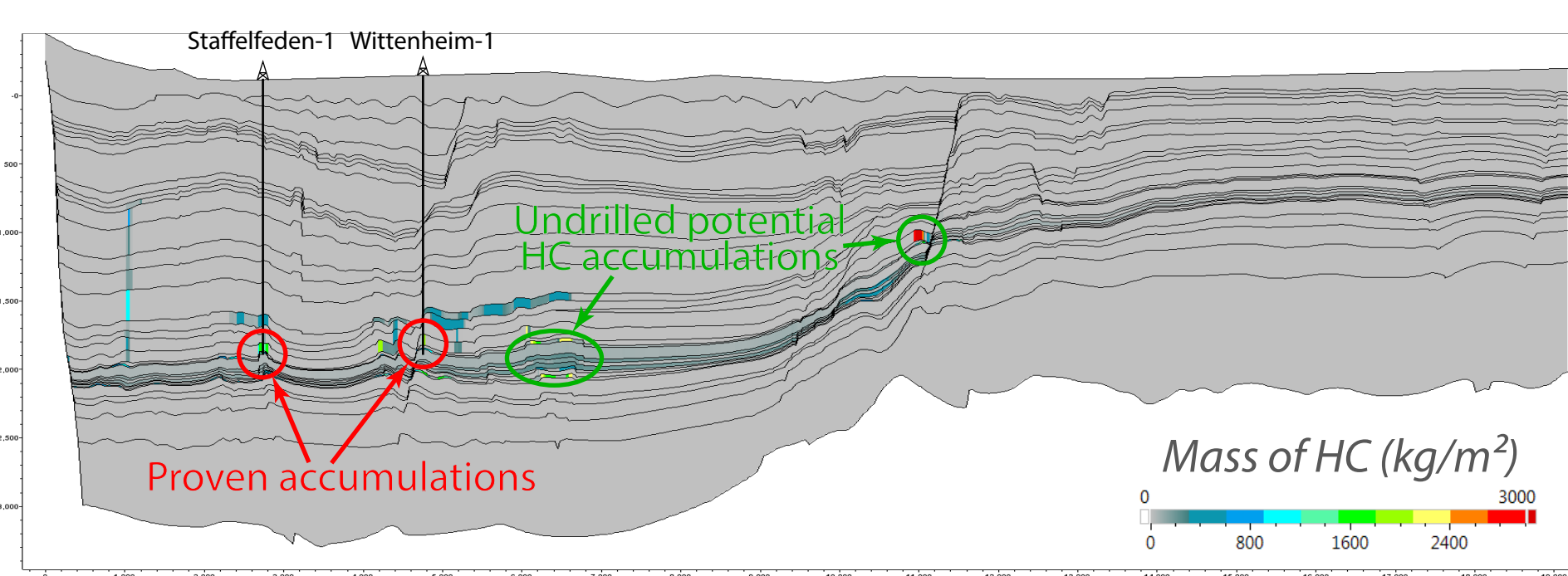


Calibration and Results



No maturity should be expected for the Tertiary SR.
Jurassic SR are mature, only if the heat flow is abnormally increased by the presence of thermal anomalies.

Full Darcy Migration



Darcy migration modeling account for **permeability**, **viscosity**, **hydrodynamism**, **capillarity** and **buoyancy** in the section plane.
Fields of Wittenheim and Staffelfeden are reproduced.
Undrilled opportunities are evidenced along the section.

CONCLUSIONS

The integrated basin modeling workflow was realized successfully from the forward stratigraphic modeling of the syn rift Cenozoic sequences to the thermal and migration modeling in 2D sections.

The burial is not sufficient to allow hydrocarbon generation and expulsion, especially in the northern part of the study area. Nonetheless, the presence of positive thermal anomalies locally increase the maturity of the Mesozoic source rocks, causing the generation and expulsion of hydrocarbon (Staffelfeden field).

Known HC accumulations along the sections were reproduced evidencing undrilled sweetspots.