

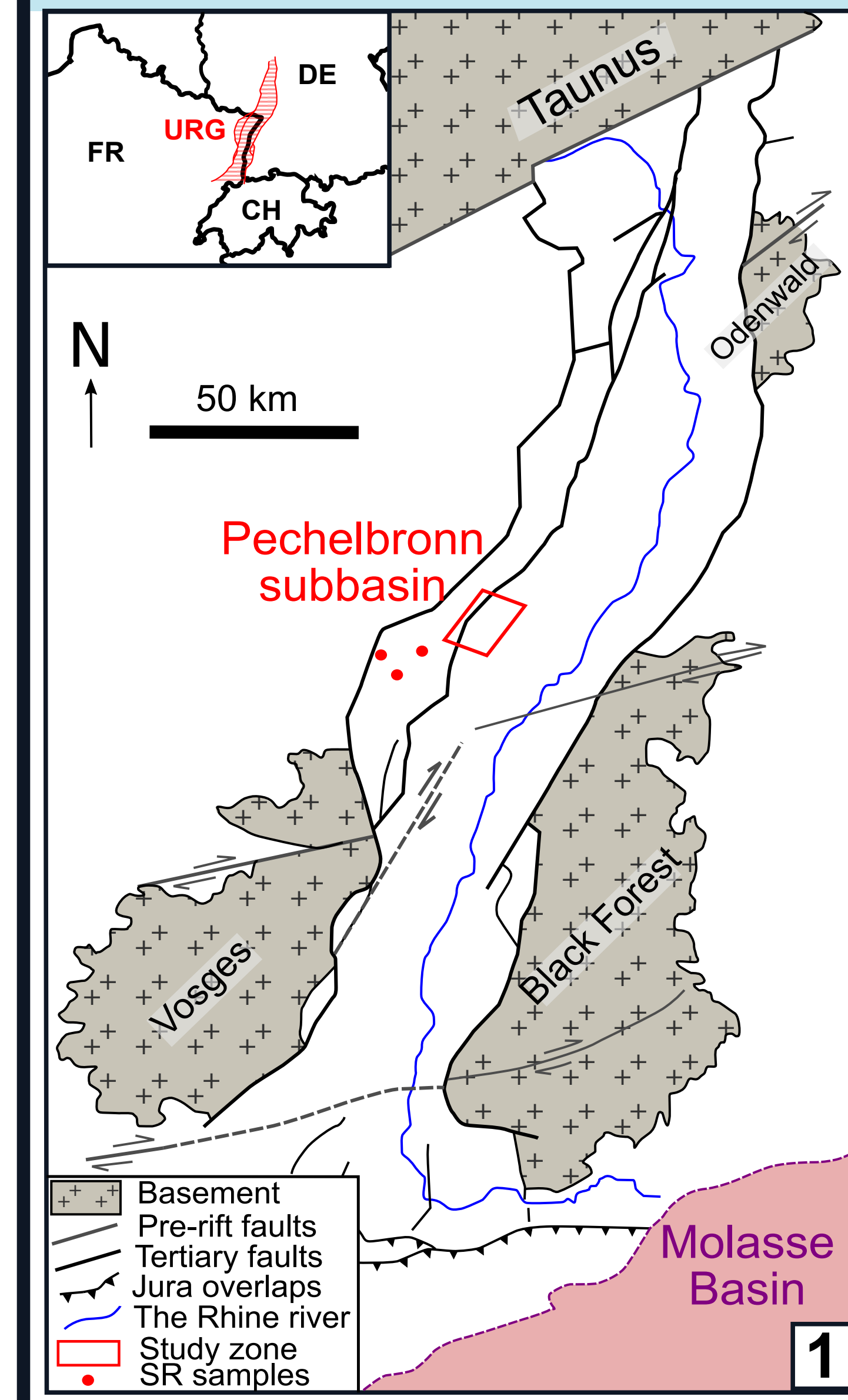
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Geological settings and study issue



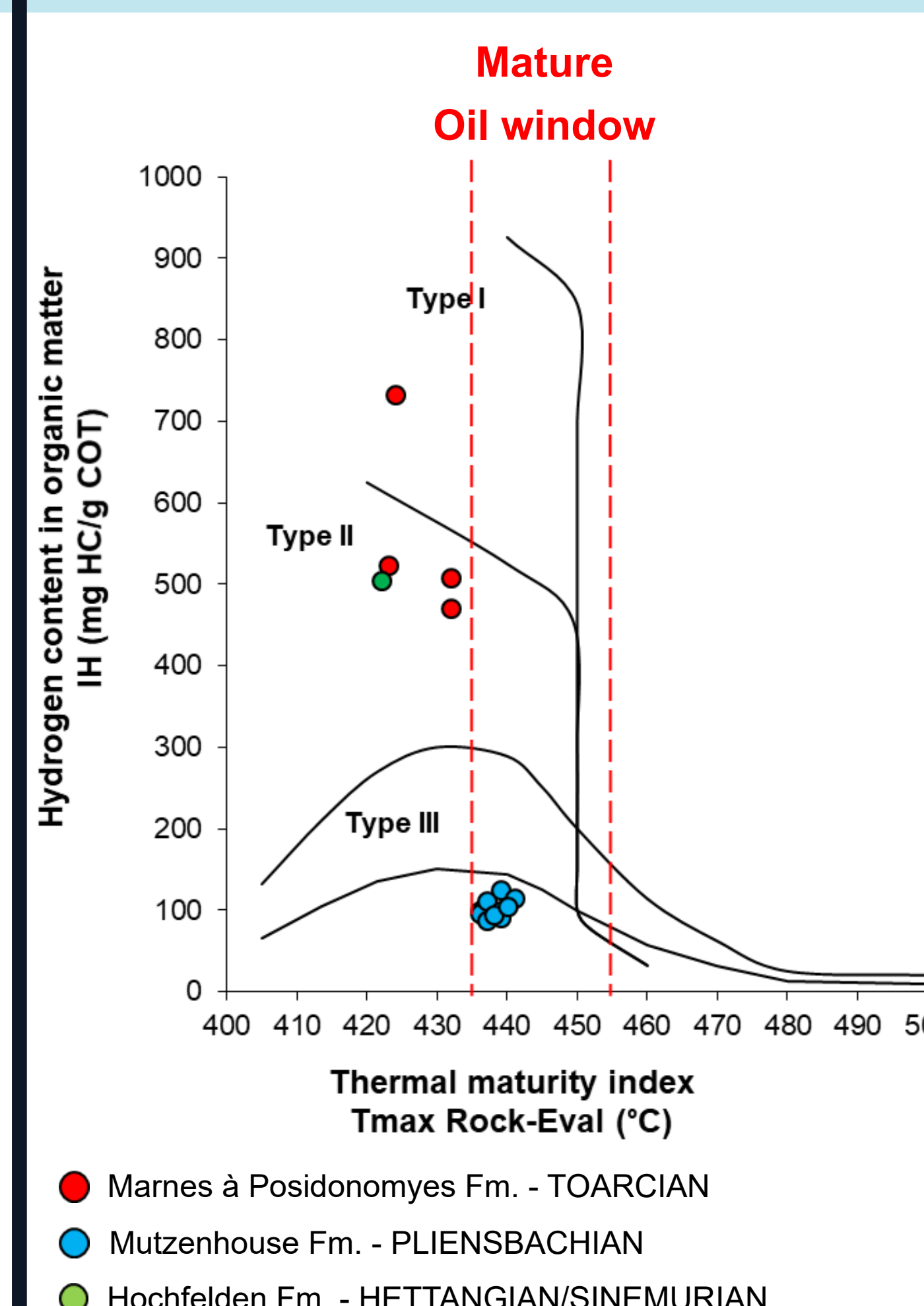
The Upper Rhine Graben (URG) is a Cenozoic intracontinental rift 300 km long and 30-40 km wide, NNE/SW trending. The study area corresponds to the Pechelbronn subsbasin, in the western central part of the URG, which holds most of the petroleum reservoirs of northern Alsace (France).

Pre-rift sedimentary filling is composed of a series of Permian to early Upper Jurassic formations, separated from syn-rift Cenozoic deposits by a major unconformity. This questions why Upper Jurassic and Cretaceous formations are missing. Especially for the Cretaceous sediments, it remains uncertain whether their absence is related to a sedimentary hiatus or a period of erosion.

The goal is to estimate Cretaceous paleoburial, which is still poorly quantified for the URG. The approach is based on basin thermal modelling (Roeschwoog 1 Well) constrained by organic markers of thermal maturity measured on surface source rock samples, located on the basin west edge which has experienced only pre-rift (Mesozoic) burial.

Figure 1. Simplified structural map of the URG with its geographical location (upper left framework), the position of the study area in red and the Mesozoic source rock sampling sites in red points.

Thermal maturity of the Mesozoic source rocks prior to the rifting



The main source rocks of the URG are Mesozoic. The IH vs. Tmax graph (fig.2) represents the degree of thermal maturity reached by the Mesozoic source rock samples collected from the URG outcrops. In this graph, the results indicate that the source rocks have Tmax values below 435°C, which means that they are immature. The Pliensbachian samples have a Tmax close to 440°C (oil window) which may in fact be related to the preservation of organic matter.

Table 1 shows the results of the S/R isomerization ratios of C₃₁ hopanes and C₂₉ steranes. The results are below 0.6 for C₃₁ hopanes and below 0.55 for C₂₉ steranes, indicating that the samples are immature. This suggests that they did not reach the oil window before Cenozoic.

Location (France)	Type	Stage	TOC (%)	T _{max} (°C)	HI (mg/g COT)	22S/22S+22R C ₃₁ Hopanes	20S/20S+20R C ₂₉ Steranes
Hattmatt	Outcrop	Toarcian	3.39	432	471	0.213	0.163
Hattmatt	Outcrop	Toarcian	3.21	432	508	0.216	0.157
Hattmatt	Outcrop	Toarcian	0.96	423	524	0.215	0.179
Hattmatt	Outcrop	Toarcian	8.03	424	733	0.286	0.211
Lixhausen	Outcrop	Pliensbachian	0.71	436	100	0.384	0.443
Lixhausen	Outcrop	Pliensbachian	0.73	436	96	0.361	0.442
Hattmatt	Outcrop	Pliensbachian	0.95	439	125	0.271	0.381
Detwiller	Outcrop	Hettangian-Sinemurian	2.9	422	505	0.441	0.428

Figure 2. IH (mg HC/g TOC) versus Tmax (°C) plot of Mesozoic source rock samples collected at the surface in the URG and its immediate vicinity.

Table 1. Summary table of some Rock-Eval pyrolysis results (TOC, Tmax, HI) and results of S/R isomerization ratio calculations of C₃₁ hopanes and C₂₉ steranes for source rock samples collected on the surface at the edge of the URG.

1D thermal model based on Roeschwoog 1 lithostratigraphy - Methodology

AGE	STRATIGRAPHIC UNITS	LITHO. MIX	THICKNESS (m)
UPPER JURASSIC	MALM	50% SH 35% CB 15% SD	60
CALLOVIAN	CALLOVIAN	50% SH 35% CB 15% SD	60
BATHONIAN	MARNES ET CALCAIRES A RHYNCHONELLA ALEMANNICA	50% SH 35% CB 15% SD	50
LOWER BAJOCIAN	MARNES DE GRASSENDORF	70% ML 6% SL 4% MICA 4% PYRITE 6% CB	134
AALENIAN	FORMATION DE SCHALKENDORF	50% SH 8% SL 8% CB	36
	FORMATION DE GUNDERSHOFFEN	45% SH 15% SD 12% CB	40
UPPER TOARCIAN	FORMATION DE PRINTZHEIM	25% ML 60% ML 2% GYPSE 3% PYRITE 10% SH	44
LOWER TOARCIAN	MARNES A POSIDONOMYES	80% BLCK SH 10% ML	13
UPPERMOST PLIENSBACHIAN	CALCAIRE DE KIRRWILLER	85% SH-CB 15 ML	69
LOWER PLIENSBACHIAN	CALCAIRE DE ZINSWILLER	80% ML 20% SH	7
SINEMURIAN	FORMATION DE BOSENDORF	80% ML 15% SD 5% CB	28
SINEMURIAN	FORMATION D'OBERMODERN	5% SH 3% PYRITE 3% MICA 40% ML	36
SINEMURIAN	FORMATION D'HOCHFELDEN	15% SH 15% SL 25% CB 2% K	8
KEUPER	RHETIEN - FORMATION DE FROESCHWILLER	14% SH 15% PYRITE 5% SD 7% GGL	10
	RHETIEN - ANGLIS DE LEVALLOIS	2.5 ILLITE 2.5 KAOLINITE 18% CB 5% SL	36
KEUPER	MARNES IRISEES MOY.	4% ANHYDRITE 75% SH 60% SD 20% SL	23
	MARNES IRISEES INF.	95% SD 5% CB DOMINATED	103
MUSCHELKALK	LETTENKOHLE - MARNES BARIOLÉES	DOLOMITE 3% GYPSE 35% SH 25% SL 5% SBK	24
	CALCAIRE A TERÉBRATULES	DOLOMITE 85% CB	249
LOWER BUNTSANDSTEIN	BUNTSANDSTEIN	80% SBK	145
PERMIAN	ROTLIENDEN	80% SBK 20% SH-SL	35

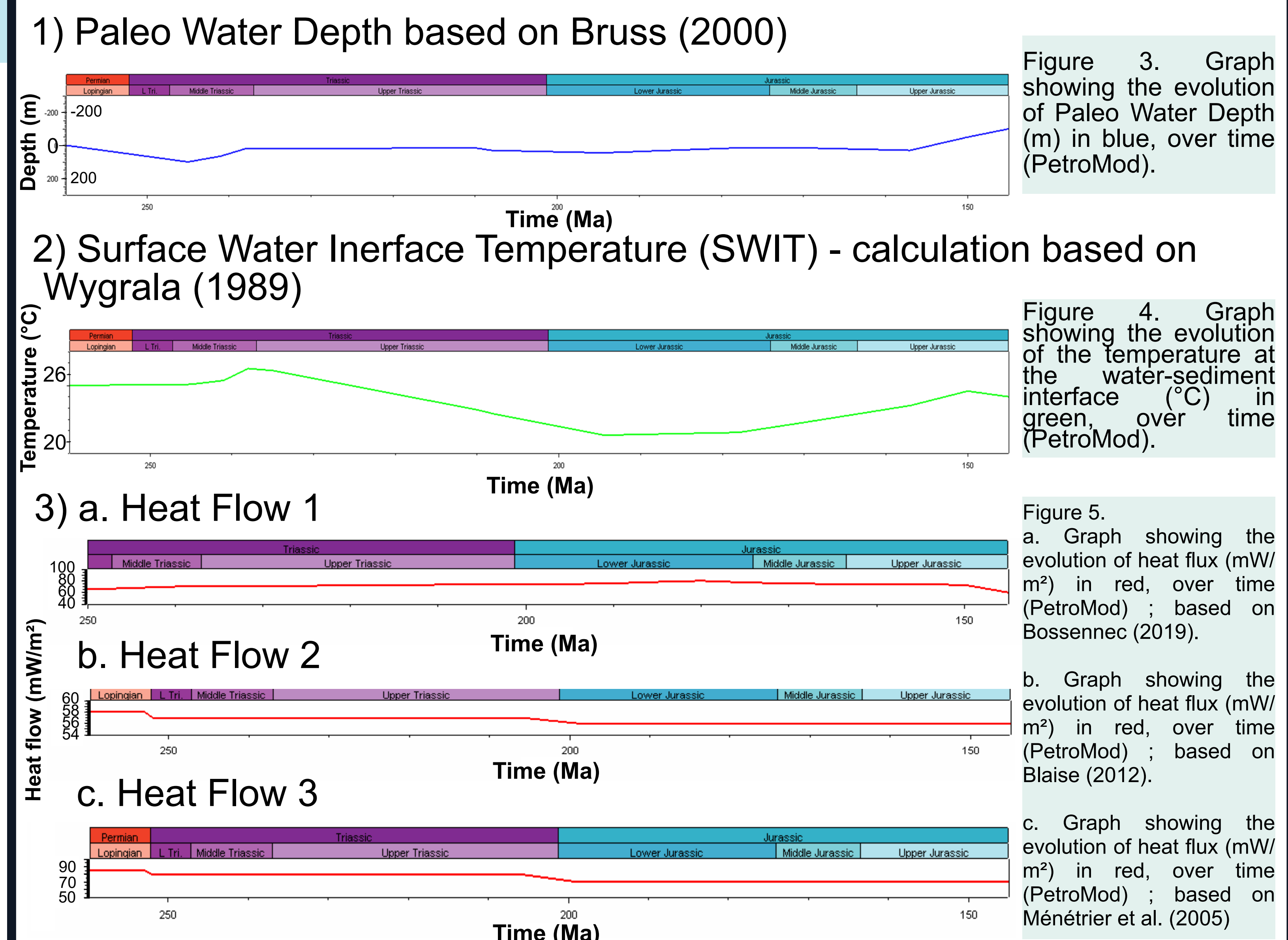
We use PetroMod software to reconstruct the thermal history of the Roeschwoog 1 Well and determine the onset of oil generation. This is dependent on temperature, burial and time. Therefore, if the time-temperature pair is fixed, it becomes possible to vary only the depth of the modelled series. With the help of thermicity markers, we can estimate the maximum thickness of sediments deposited above the source rocks, before the URG was formed.

The method for calibrating 1D basin thermal models from organic geochemistry consists of comparing the values simulated by the 1D thermal model (based on Mackenzie et McKenzie, 1983) with the values calculated on the molecular markers of thermicity (S/R isomerization ratios of outcrop samples). Here we fix the time (late Permian to late Jurassic) and test 3 different heat flows and 5 potential thicknesses of Malm: 150, 200, 250, 300 and 400 m.

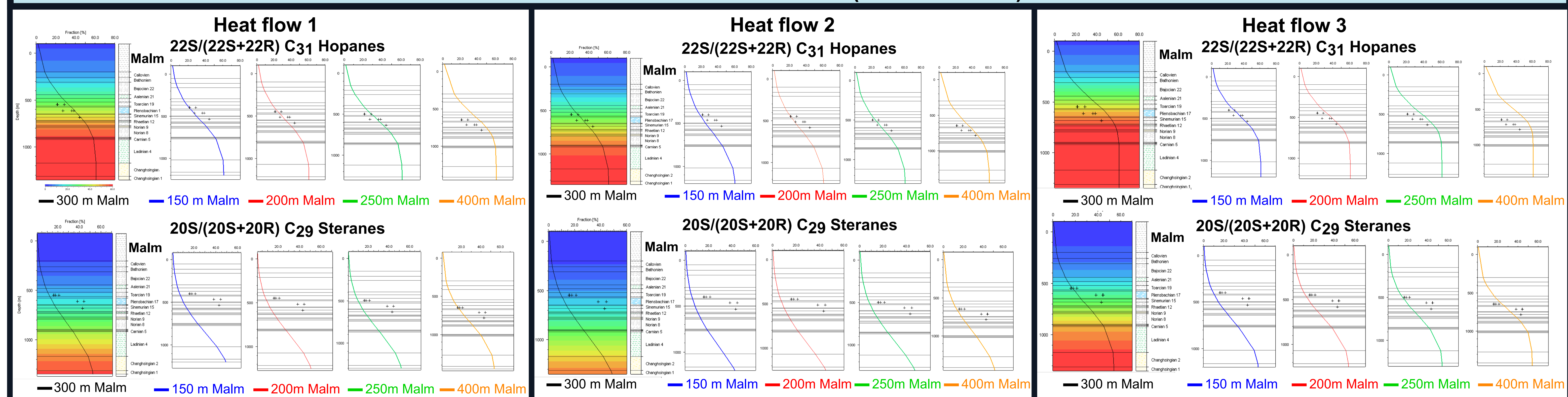
Table 2. Compilation of the Roeschwoog 1 stratigraphic units with their relative age, lithological mix and thickness. The absolute ages were defined according to Cohen, M.K. et al. (2019). The lithological mixes were defined arbitrarily on the basis of Ménéillet et al. (2015) and the borehole report (InfoTerre). The thicknesses were taken from the borehole reports and the well was extended from the base of the "Couches à cératites" to the basement from the GeORG model (2014).

Lithological mix abbreviations : Cgl : Conglomerate ; Sbk : Subarkose ; Sd : Sandstone ; Sl : Siltstone ; Sh : Shale ; Blck Sh : Black Shale ; Cb : Carbonate ; MI : Marls

Boundary limits applied from late Permian to late Jurassic



Simulation results - Calibration of the model by fitting calculated curves (Mackenzie & McKenzie, 1983) with the measured values (black crosses)



The calibrations appear to be more relevant using the S/R isomerization ratios of C₃₁ hopanes than those of C₂₉ steranes. This may be because the values are highly dependent on facies (as in Blaise, 2012), which makes it difficult to identify a trend driven by low maturities. For Heat Flow 1 simulations and with regard to the simulation results obtained on the C₃₁ hopanes, it can be observed that the calibrations are better constrained by a Malm thickness of between 200 and 250 m. For Heat Flow 2 simulations, it can be observed that the calibrations are better constrained by a Malm thickness of between 250 and 300 m. For the Heat Flow 3 simulations, the calibrations are better constrained by at least less than 150 m of Malm. For the 3 different Heat Flow models, the addition of 400 m of Malm seems to be overestimated.

The next objective is to test this calibration method on a dozen wells located in the Pechelbronn basin. Also, in order to better calibrate the models, the same isomerisation calculations will have to be done on Keuper and Muschelkalk outcrop samples.