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PETROLEUM SYSTEM STRATEGY APPLIED TO GEOTHERMAL FIELDS: THE CASE OF THE PECHELBRONN SUB-BASIN (FRANCE)

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The Upper Rhine Graben (URG) is a Cenozoic intracontinental rift presenting local thermal anomalies, which have focused research attention in the development of deep geothermal energy and recently in lithium extraction from geothermal brines (e.g., Sanjuan et al., 2022). These recent exploration concerns raise questions about the quantification and hydrothermal fluid dynamics in the URG at the basin scale. These challenges arise primarily in the Pechelbronn sub-basin located in the western central part of the URG, which hosts geothermal (Soultz-sous-Forêts and Rittershoffen, France) and petroleum fields. The reconstruction of the geological evolution of the basin in regards to fluid generation and migration is required for the understanding of existing underground resource distribution in time and space.

Recent studies demonstrate that the present-day high geothermal gradients are mostly the result of convective hydrothermal cells located along graben-parallel fault systems (e.g., Bächler et al., 2003; Baillieux et al., 2013). The presence of petroleum associated to the hydrothermal fluids suggests that these fluids follow at least partly the same circulation pathways. Although hydrothermal fluids are confined to fault systems at the basin scale, it seems likely that the thermal maturity of organic matter was also affected by the convective hydrothermal cells. This raises concerns in the reconstruction of the basin thermal history, commonly calibrated with organic thermal maturity markers.

In this objective, we completed the organic geochemistry characterization on a collection of rocks and oils both from outcrops and wells. 1-D basin thermal modelling was calibrated using basin burial history coupled with biomarkers thermal maturity measurements. Specific application to the Saverne fracture field allowed to set the early paleothermal conditions of the URG. Basin thermal modelling and seismic lines analysis, show that peak of oil generation reached during late Oligocene within marine source rocks located beneath a thick Cenozoic marl-clay cover. This might have caused overpressure as suggested by fluid inclusions pressure determination. Expulsion/migration could therefore only occur once post-rift faults developed in the basin. Fast release of pressure during faulting may have led to gas phase separation and losses which would explain the scarcity of gas in the reservoirs of the oil fields. The north-south striking faults system also allowed migration of hydrothermal fluids from basement/sediment interface, triggering the emplacement of convective cells responsible for local geothermal anomalies. Consequently, the 2-D thermal modelling of the current structural configuration of the Rittershoffen area calibrated with organic thermal maturity markers aims at the estimation of the timing of the hydrothermal cells emplacement. This study is thus an example on how petroleum system analysis can bring background to the formation of geothermal fields through space and time.

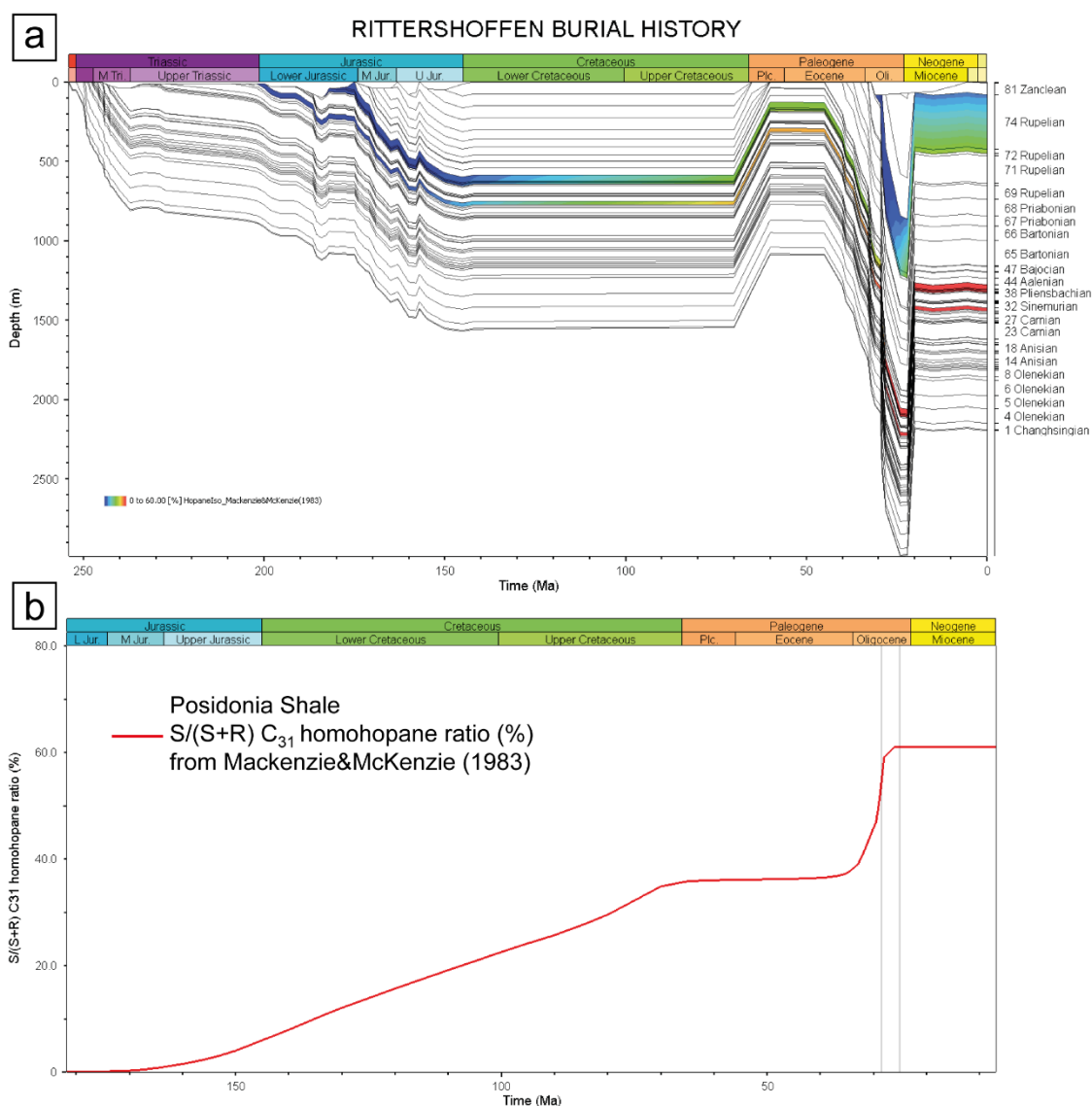


Figure 1 1D thermal and basin burial history based on the GRT-1 geothermal well (Rittershoffen, Alsace, France) using PetroMod[®] software. *a.* Burial history from late Permian to present-day based on GRT-1 well. Colored overlay: simulated thermal evolution calibrated with measurements of S/(S+R) C₃₁ homohopane ratio (%) using Mackenzie&McKenzie (1983) kinetic parameters. *b.* S/(S+R) C₃₁ homohopane ratio (%) in function of time (Ma) for the Toarcian Posidonia Shale, using Mackenzie&McKenzie (1983) kinetic parameters.

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