MODELING OF PETROLEUM GENERATION IN THE BANAT DEPRESSION (PANNONIAN BASIN)

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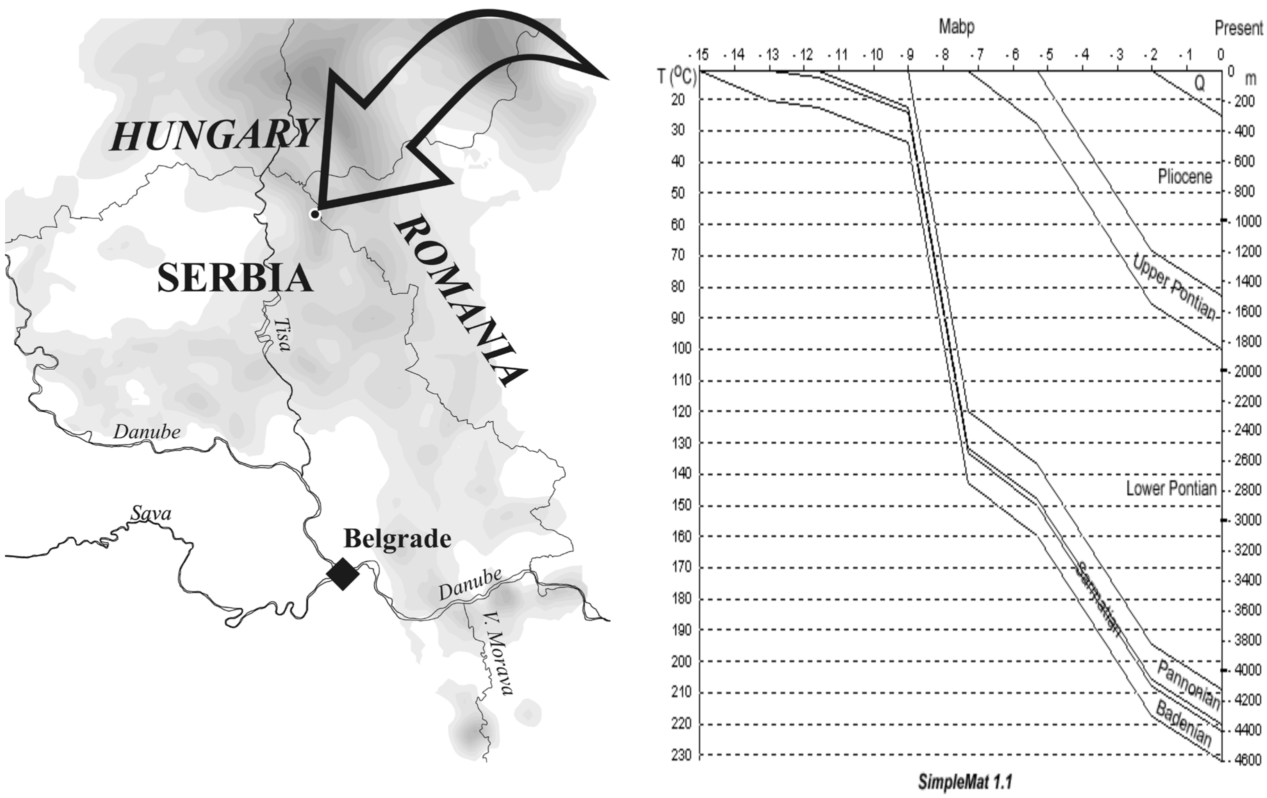
Abstract: The results of kinetic modeling for the Miocene oil-source rocks in the deepest part of the Banat depression shows that the oil window corresponds to the temperature interval from 110-120°C to 165°C. The substantial transformation of kerogen, and, consequently, the possible oil expulsion, corresponds to the temperatures of about 120–132 °C. The generation of gas from the Pontian gas-source rocks has taken place at the temperatures of about 130°C to 210°C, and significant cracking of oil into gas begins, according to the adopted model, at the temperature of about 165 °C.

Key words: Petroleum, Source rocks, Kerogen, Kinetic models, Banat depression, Pannonian basin.

Kinetic modeling of petroleum generation is based on the fact that kerogen maturation depends on temperature, the heating rate and the corresponding activation energies. The degree of the transformation of kerogen into hydrocarbons is calculated on the basis of the Arrhenius equation of chemical kinetics. In addition to the determination of the kinetic parameters of petroleum generation, it is necessary to make a reconstruction of the burial and geothermal history of the source rocks. The specific kinetic parameters are obtained by the simulation of hydrocarbon generation using the method of controlled laboratory pyrolysis of the Rock-Eval type or by hydrolysis. If no real kinetic parameters are available, use can be made of the published values for the corresponding type of kerogen, as has been done in this paper.

The part of the Banat depression chosen for modeling was its deepest depocentre (4600 m), which is located in northern Banat (Fig. 1-A). This choice was made because the highest temperatures were attained in this depocentre, which makes it possible to study all the phases of hydrocarbon generation and cracking. The geothermal gradient in this depocentre is 4,8 °C / 100 m, and the relative depths, temperatures and absolute ages of its chronostratigraphic units are shown in the burial history diagram in Fig.1-B.

The effective source rocks for oil and gas in this part of the Banat depression are Baden-Sarmatian and Pannonian pelites, and principle gas-source rocks are sediments of the Lower Pontian (Kostić, 2000). Since oil-source rocks contain mainly the hydrogen-rich type II kerogen, and the Lower Pontian (9-7 Mabp) contains type III kerogen, the boundary between the Baden-Sarmatian and Pannonian sediments (base of Pannonian) has been used for the calculation of the transformation of type II kerogen, while the base of the Lower Pontian, which is the main source of gas in this area, has been used for type III.



A **B**

Fig. 1. A - *Location of the deepest Banat depression depocentre modeled in this study. The shaded area represents the Cenozoic sediments thickness of over 1000 m.*
B – *Burial and temperature history diagram for the modeled Cenozoic sequence.*

The earlier kinetic modeling of the geothermal history of the broader area of the Banat depression comprised the vitrinite reflectance model - EASY %Ro (Kostić & Ercegovac, 1998), and the presentation of the “SimpleMat” software (Ercegovac, *et al*., 1998) with the first results obtained by the TTI_{ARR} kinetic model (Kostić, *et al*., 1998).

This study applies various modern kinetic models, such as the parallel reactions models for total hydrocarbons (kinetic parameters according to Schafer *et al*., 1990), models for oil with a single set of kinetic parameters (TTI_{ARR} - Hunt, 1996), as well as models which treat separately oil, gas and cracking with parallel reactions according to Gausian distribution of activation energies (parameters according to Mackenzie & Quigley, 1988). In the latter case, a discretisation of Gausian distribution was made before the construction of the model, that is, separate activation energies and the fractions of the total reaction corresponding to them were determined for each 1,5 - 2 kcal/mol interval, taking into consideration the published values of standard deviations.

The numerical simulations were made by means of the standard «spreadsheet» software, and the algorithm for parallel reaction models corresponded to that published for the EASY % Ro model (Sweeney & Burnham, 1990). In doing this, it was necessary to modify the kinetic parameters to make them correspond to the specific type of kerogen rather than to vitrinite.

Fig. 2 shows the results of the kinetic modeling of oil generation using the kinetic parameters for the usual type of kerogen – IIC and the slightly more reactive IIB type (classification according to Hunt, 1996), as well as for the «labile» oil-productive kerogen (classification according to Mackenzie & Quigley, 1988). The more reactive IIB type (richer in sulphur content) is hardly likely to be present in the modeled sequence, so the results relating to it are not separately interpreted in the text.

The obtained transformation curves indicate that the oil window is located, depending on kinetic parameters, within the temperature range from 110-120^{o}C to about 165^{o}C. Substantial transformation of kerogen into oil (over 10 %), and, consequently, its possible expulsion from source rocks can be expected at the temperatures of over 120 – 132 ^{o}C. The peak of oil generation (transformation 50%) corresponds to the temperatures of 135-148 ^{o}C, and transformation ends at the temperatures of 150-170 ^{o}C.

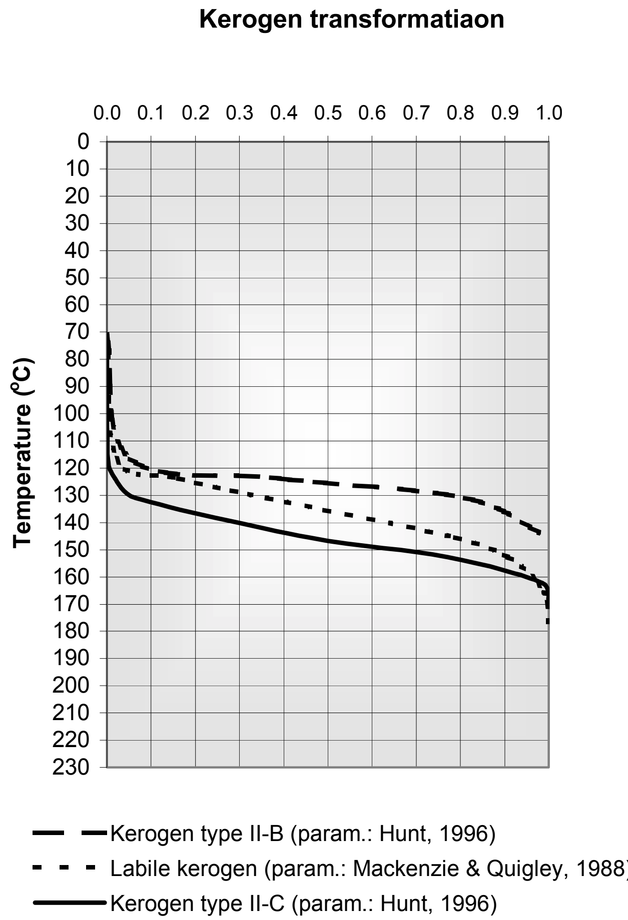
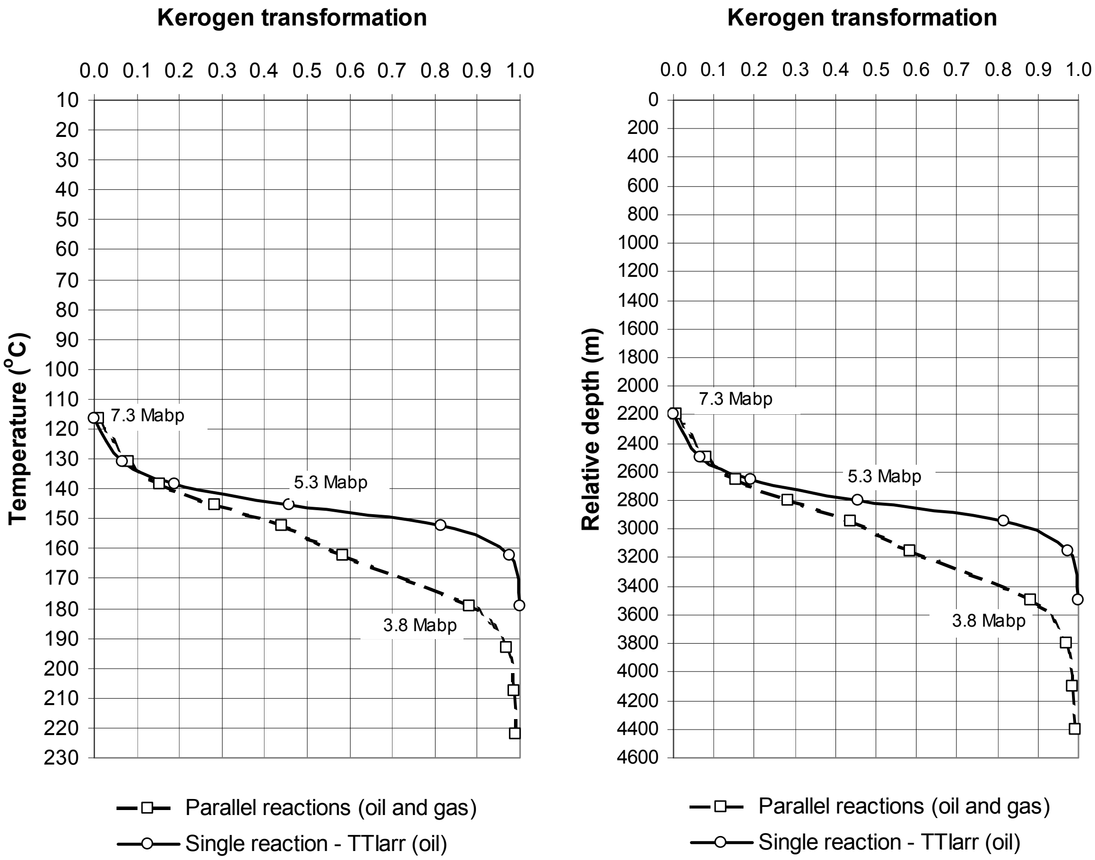


Fig. 2. *The transformation of kerogen from Baden-Sarmatian and Pannonian source rocks into oil, according to kinetic models for type II kerogen.*

The variations analysis of the hydrogen index from the Rock-Eval pyrolysis indicates that the kerogen of the Baden-Sarmatian and Pannonian source rocks shows great similarity with that of the Lower Toarcian source rocks of the Paris basin (Kostić, 2000). Therefore the kinetic parameters for the Lower Toarcian shale published by Schafer *et al*. (1990) were used for the total hydrocarbons in the parallel-reactions kinetic modeling. The results are shown in Fig. 3, which includes, for the sake of comparison, the already presented curve of oil generation from the corresponding type IIC kerogen.



A **B**

Fig. 3. *The degree of the transformation of type II kerogen in relation to the rise of temperature (A) and relative depth (B). The dotted line shows the transformation of kerogen into hydrocarbons according to the parallel reactions model (according to Schafer et al., 1990), and the full line indicates the degree of the transformation of kerogen into oil according to the TTI_{ARR} model (type IIC; parameters after Hunt, 1996).*

The results of the model for total hydrocarbons show that generation (of oil first) might have started at the beginning of the Upper Pontian (7,3 Mabp), at the temperature of about 120°C (2200 m), and that more substantial transformation of kerogen took place at the temperature of about 130°C (2500 m). The peak of the generation of total hydrocarbons corresponds to the Dacian (5 Mabp) and to the temperature of 157°C (3000 m). As much as 90 % of kerogen transformation was completed by the beginning of Romanian (3,8 Mabp) at the temperature of 180°C (3500 m), and small quantities (of gas) are still being generated.

The analysis of the transformation of type III kerogen from the Lower Pontian source rocks includes only the results of the modeling for gas (Fig. 4), since these source-rocks contain a low concentration of $C_{org,}$ insufficient for the substantial generation of oil from the kerogen of this type. The models used were the parallel reaction model with the parameters according to Yalcin *et al.* (1994) and the model for gas generation from refractory kerogen – with Gausian distribution of activation energies (according to Mackenzie &. Quigley, 1988).

The kinetic models shown in Fig. 4 indicate that the generation of gas from the Lower Pontian sediments might have taken place at the temperatures of about 130°C, with a more substantial transformation (over 10%) at 150-160°C (depending on the model). The peak of gas generation corresponds to the temperatures of 170-190 °C, and the transformation of 90 % in both kinetic models corresponds to the temperature of 210°C, which is also the maximum temperature in the Lower Pontian sequence in the Banat depression. Since the Lower Pontian sediments in the depocentre attained the temperature of 130-150 °C at the beginning of Pliocene (5,3-4,5 Mabp), the generation of gas probably started in the Dacian.

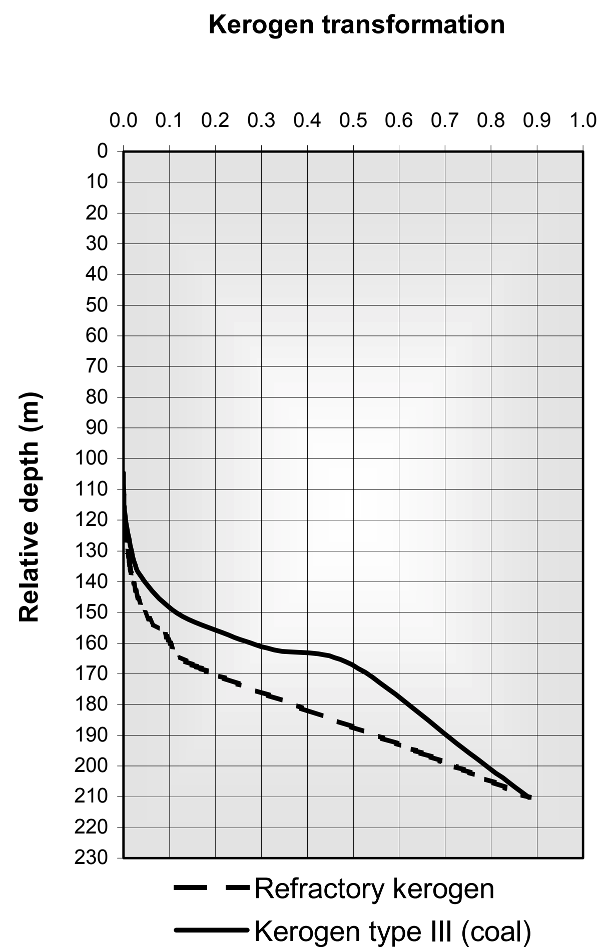


Fig. 4. *Transformation of kerogen from the Lower Pontian sediments into gas in relation to temperature rise according to the kinetic parameters for type III kerogen.*

As regards the cracking of oil into gas (Fig. 5), two fairly well known sets of kinetic parameters give basically different results. According to the parameters published by Mackenzie & Quigley (1988), considerable cracking of oil (transformation 10%) would occur in this depocentre at the temperature of about 166°C, and one half of the transformation would be completed at around 185°C. This model also shows that oil virtually cannot exist at temperatures exceeding 200 °C (transformation 90%). On the other hand, the application of the parameters obtained by Horsfield *et al*. (1992) yields a considerably slower transformation, which reaches 10 % only at 210°C, when intensive cracking begins (50 % already at 220°C). If we bear in mind that only accumulations of condensates have been discovered so far in the Pannonian basin at temperatures exceeding 175-180°C, we may conclude that the parameters after Mackenzie & Quigley (1988) are probably more suitable for the Pannonian basin.

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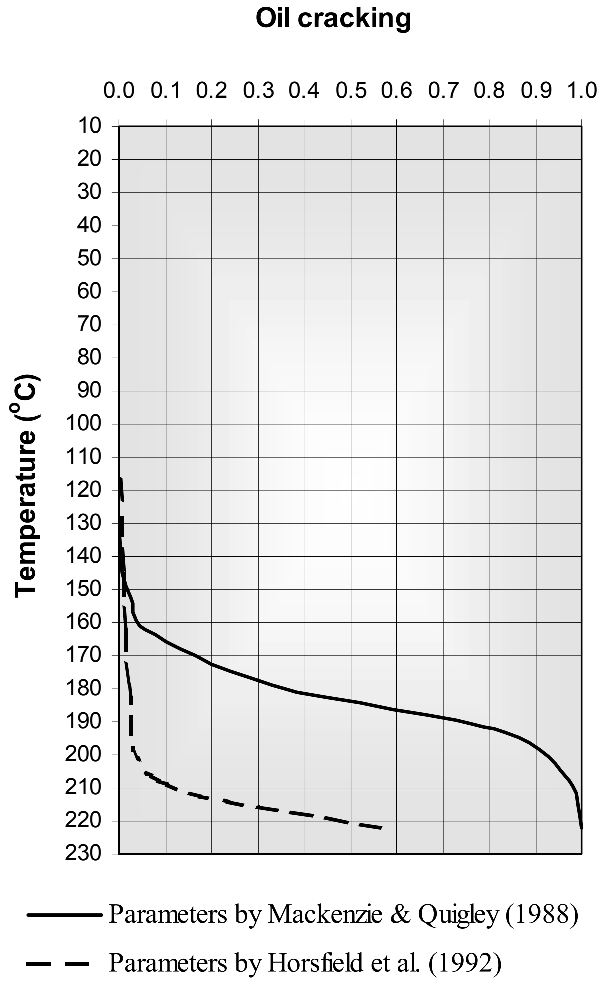

Fig. 5. *The cracking of oil into gas according to the kinetic parameters of Mackenzie & Quigley (1988) and Horsfield et al. (1992).*

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