Biogenic reactions and methane expulsion modelling from source rocks of Ravneš Member, Sava Depression

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Abstract

In the evaluation of the initial hydrocarbon prospectively of the entire Lonja Formation (approximate Pliocene, Pleistocene and Holocene sequence), the Lower Pliocene Ravneš Member was used as analogy. In this member we tested the possibility of the HC generation based on biogenic reactions.

This member bears large volumes of coal and organic rich clays with type III and IV kerogene. The current depth of this member is a maximum of -1300 m in the deepest part of the Depression and the timing is sufficient for releasing the biogenic derived methane. Ravneš Member, as well as the whole Lonja Formation is being tested for HC potential based on the analogy of the Adriatic offshore biogenic gas accumulations of large volumes and frequent gas shows in the shallow intervals within the research area. Structural model was obtained from previous research. Facies maps of Ravneš Members were made using the combination of neural networks for input preparation and using convergent interpolation for actual mapping. Spatial distribution of geochemical properties was also mapped trough the exploration area. Generation potential was obtained by 3D basin modelling in Schlumberger PetroMod software.

Key words: Basin modelling, biogenic reactions, Pliocene, Sava Depression, Croatia

1. INTRODUCTION

Miocene sequence in the area is relatively well explored and with proven gas and petroleum potential. As a proof of this, there are total of 17 oil and gas field in the area, majority of which are still in the production. Largest amounts hydrocarbon reserves belong to the oil as in time of the most active exploration within the Sava Basin (1950 – 1990) natural gas was considered as a far less worthy resource when compared to oil. Today, natural gas accumulations are explored and considered a strategic resource. Analogy for research of young sediments can be found in Adriatic gas accumulations which are basically bio – methane which is a result of bacterial degradation of organic matter. Type of organic matter in Pannonian Basin Pliocene sequence is similar in composition, Type III and IV kerogene, and maturity (Vulama, 1997; Cvetković, 2013; Barić, 1993). Gas accumulations in the Adriatic hold large reserves. For example, Ivana Gas Field in its start of the production had 8 x 10^9 of recoverable reserves of natural gas (ZELIĆ et al., 1999) and the probability of finding a similar amount of these volumes in the Pannonian Basin System Sava Depression in similar sediments is a good enough reason for detailed explorations.

2. GEOGRAPHICAL AND GEOLOGICAL SETTINGS

Investigation area belongs to the south-eastern part of the Pannonian Basin System, more accurately Sava depression. It covers roughly around 340 square kilometres and is located between Ivanić Grad on the North, Lipovljani on the East and Moslavačka gora Mt. on the North (**Figure 1**).

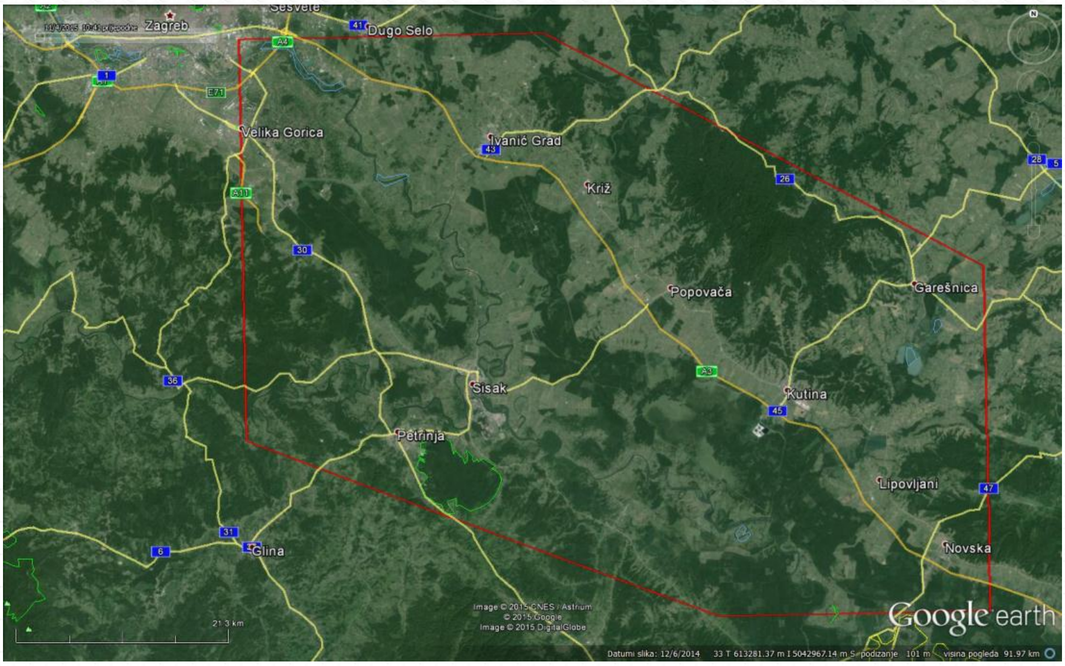

Figure 1: *Outline of the exploration area*

Investigated stratigraphic section belongs to a one of the youngest parts of the Quaternary-Neogene infill of the PBS – namely Lower Pliocene Ravneš member. The whole Neogene sequence can be up to 3500 m thick in the explored area (Saftić et al., 2002) and is composed of conglomerate and breccia (pre-Badenian), limestone and calcarenite (Badenian), sandstones and marls (Sarmatian, Pannonian and Pontian) and poorly consolidated sandstones, sands and clays (Pliocene and Quaternary). Ravneš Member is part of the Lonja Formation along with five other members (**Figure 2**). It was selected for this preliminary analysis of hydrocarbon potential because of its lithological composition as it is in some parts almost exclusively composed of coal and in other parts holds large percentage of coal in its total thickness.

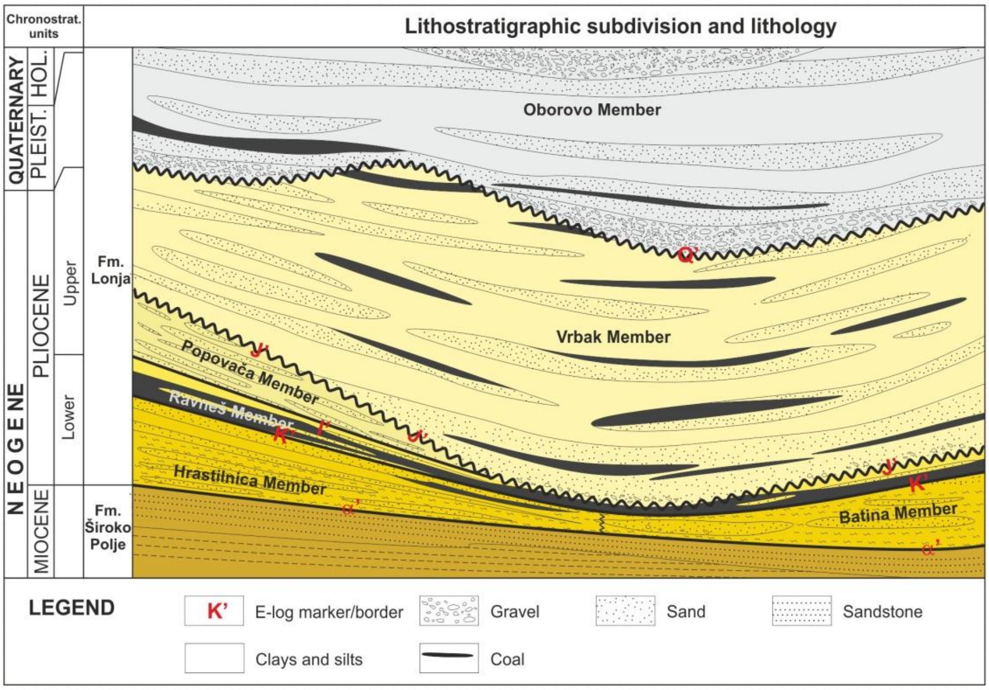

Figure 2: *Lithostratigraphic subdivision of Lonja Fm. (Cvetković, 2013)*

3. METHODS

For this kind of "Basin research" approach steps that needed to be taken or obtained from previous research for this kind of preliminary research are: (1) structural modelling, (2) lithology definition (3) organic geochemistry properties and kinetics definition, (4) Basin modelling and calibration. Part of the process was made done using the Schlumberger Petrel software (structural modelling, lithofacies mapping) while the basing modelling was done using the Schlumberger PetroMod software.

3.1. Structural modelling

A subsurface model of Pliocene Pleistocene and Holocene sediments divided by 4 E-Log markers and six Members was built based on Cvetković (2013). E-log markers were defined by standard deviation curves and represent a general lithological change controlled by tectonics and environment influence (Cvetković & Velić, 2014). The targeted Ravneš Member is located between E-log markers K' and I' or J' (**Figure 2**), depending on the location trough the depression. Its thickness varies from 0 m on the edges to 167 m in the deepest parts of the depression. The thickest sediments are found in the vicinity of Kos-1 well but the classic lithology can be found within the Rv-1 well. Initial modelling was made in Petrel (Cvetković, 2013) but for the basin modelling surfaces of each well log markers and the topography were transferred to PetroMod software in which the cell based model was re-built (**Figure 3**).

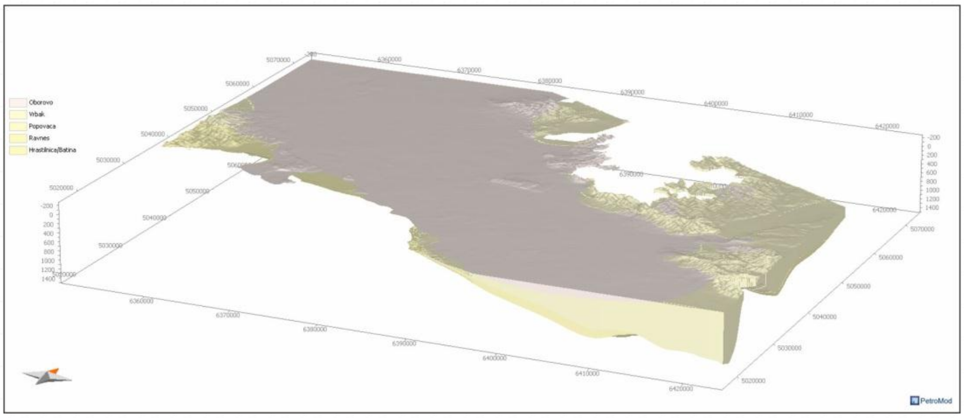

Figure 3: *Model of the Lonja Formation infill*

3.2. Lithology definition

Lithofacies analysis defined the member as impermeable, shale like dominant facies. More detail analysis showed that this Ravneš Member is made from coal (lignite) and organic rich clay based upon master log data of cutting and fragments. Resistivity curves also indicate coal layers (Cvetković, 2013). A percentage of coal (value is a continuous variable ranging from 0 to 1) in Ravneš member was mapped based on well data using the 26 wells from within the area. Two approaches were used, a relatively classic mapping approach using the Convergent interpolation algorithm which obtains relatively smooth transition as a generally good algorithm for mapping structural surfaces in the subsurface. The maps show relatively gentle transitions (**Figure 4b**) depicting a less realistic image when compared to real world transition of facies. Second approach was using the Sequential Gaussian Simulations (SGS) by which a more realistic looking map was made with abrupt facies transitions (**Figure 4a**) which are characteristic for the Pliocene environments in Sava Depression (Cvetković, 2013). Two maps were then used as facies maps for the Basing modelling process. A total of six lithologys were defined: pure shale (clay), pure coal and four mixed transition lithology with different amounts of coal and shale (**Table 2**).

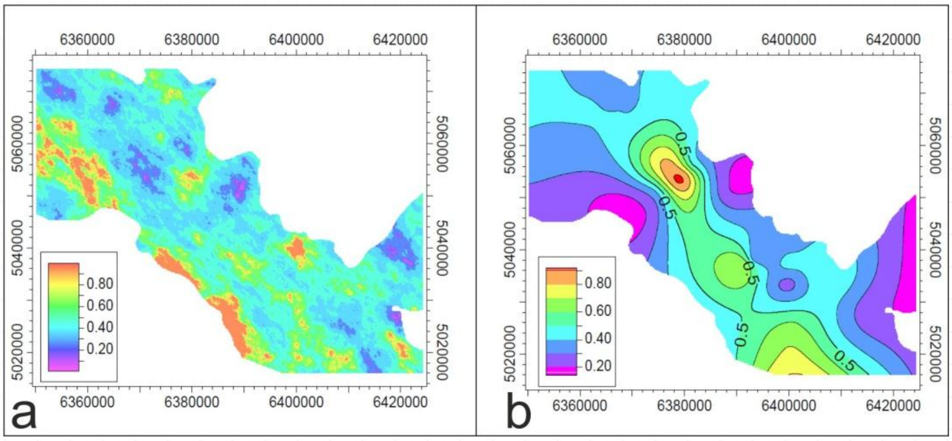

Figure 4: *Maps of coal distribution in Ravneš Member expressed as percentage in member thickness (% - 0-1) made by SGS (a) and convergent interpolation (b)*

3.3. Organic geochemistry properties and kinetics definition

Organic geochemistry data for coals and clays of Ravneš members were obtained from Barić (1993) and Cvetković (2013). The coals and clays show dominantly Type III gas prone kerogene in immature stage. At the moment biogenic reactions should be at the ending stage in the deepest parts of the Depression (**Figure 5**) defined by the transformation rate (TR). Organic geochemistry properties are similar to the ones in the Northern Adriatic (Vulama, 1997, Marić Đureković, 2011). Properties of selected coals from Ravneš Member are shown in Table 1 along with the several samples obtained from the member in the top and base of Ravneš Member along with organic rich clays. These properties were then assigned to the Ravneš Member facies defined in PetroMod (**Table 2**). Kinetics was set for biogenic reactions.

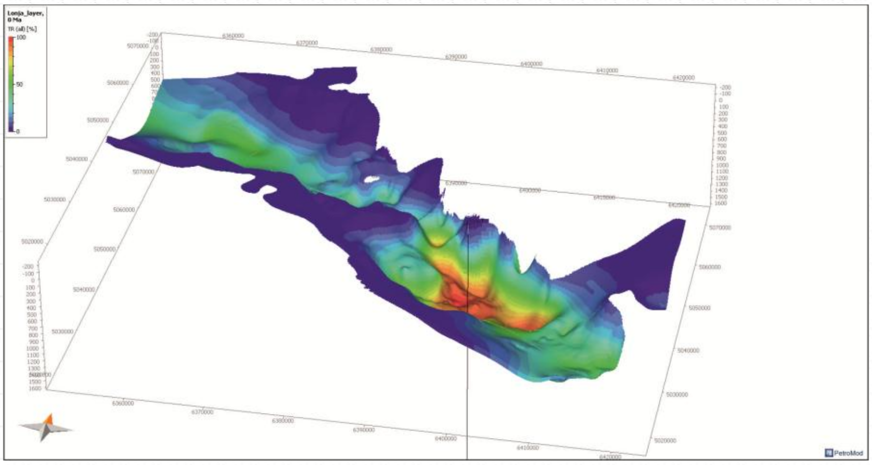

Figure 5: *Transformation rate (TR) of the organic matter by biogenic reactions at present day*

Table 1: *Geochemical properties of coals and organic rich clays from Ravneš and adjacent members (Cvetković, 2013)*

	TOC (%)	HI (mg HC/ g C_{org})	OI (mg CO_2/ g TOC)
Sample 1	4.02	64	227
Sample 2	32.15	103	142
Sample 3	39.86	200	137
Sample 4	7.71	71	390
Sample 5	29.10	74	127

3.4 Basin modelling –data processing and calibration

The model output is basically generated automatically based on all of the data provided in the input, along with defined boundary conditions. These boundary conditions are surface water interface (SWIT), heat flow (HF) and the paleo water depth (PWD). This data can be altered during each modelling step so the modelled temperature and vitrinite reflectance (VR) correspond to the actual ones in the wells. Heat flow was set at a 70 mW/m^2 as shown in Lenkey et al. (2002).

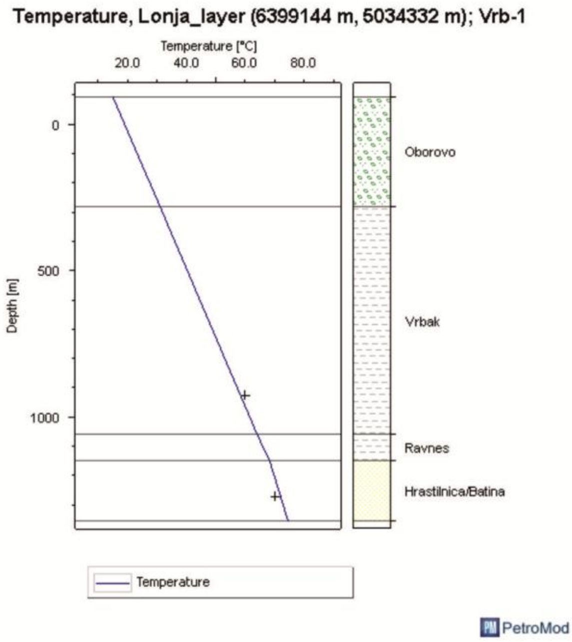

Figure 6: *Temperature calibration of the model based on well temperature data from well Vrb-1*

Calibration was made only with the fitting of the temperature values (**Figure 5**) as VR is a poor indicator when dealing with immature source rocks. The model was only made for temperature and generation as for migration; more detailed facies distribution data of other formations should be obtained.

Table 2: *Lithology and organic geochemistry definition of the Ravneš Member facies*

Lithology	PetroMod lithology	TOC	Kinetics	HI value	PSE
Ravnes_clay	Shale (typical)	1.00	Biogenic_Reaction	70.00	Source Rock
Ravnes_Sh80Co20	Sh80Co20	5.00	Biogenic_Reaction	80.00	Source Rock
Ravnes_Sh60Co40	Sh60Co40	10.00	Biogenic_Reaction	85.00	Source Rock
Ravnes_Sh40Co60	Sh40Co60	15.00	Biogenic_Reaction	90.00	Source Rock
Ravnes_Sh20Co80	Sh20Co80	20.00	Biogenic_Reaction	100.00	Source Rock
Ravnes_coal	Coal	35.00	Biogenic_Reaction	120.00	Source Rock

4. RESULTS AND CONCLUSION

An estimate of possible generated hydrocarbons – biomethane, was obtained for two cases – the convergent interpolation and the SGS lithology definition approach. Both showed substantial amount of biomethane generated – 150.473 x 10^9 m^3 for the convergent interpolation model and 478.276 x 10^9 m^{3}for the SGS. These are substantial amount for only one part of the Lonja Formation and if only

1 % of these reserves were preserved in the accumulations of economic value than the Lonja Formation layer provide a favourable exploration object. The differences in volumes generated resulted in different facies distribution between the convergent interpolation and the SGS lithofacies maps. Although the convergent interpolation provides a safer result, the SGS is more corresponding to the environment characteristics which were in power during the lower Pliocene is Sava Depression and cannot be disregarded. Further step is building of a detailed lithofacies model of remaining Lonja Formation member, calibration on several locations and calculation of the possible accumulations and their location. Volumes of organic rich sediments in Hrastilnica and Vrbak members cannot be disregarded and may provide substantial amounts of biomethane for possible trapping.

5. ACKNOWLEDGEMENTS

Authors would like to thank the Schlumberger Company for providing the Academic licences of Petrel and PetroMod Software without which this kind of analysis, in its current extent, would not be possible.

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